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OF

DAIRY BACTERIOLOGY

A CONCISE MANUAL FOR THE USE OF STUDENTS IN DAIRYING

BY

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NINTH EDITION
WHOLLY REWRITTEN

MADISON, WISCONSIN
H. L. RUSSELL
1910

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STATE JOURNAL PRINTING COMPANY
PRINTERS AND STEREOTYPERS
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PREFACE TO THE NINTH EDITION.

This text was originally the outgrowth of a series of lectures on the subject of dairy bacteriology to practical students in the Dairy Course in the University of Wisconsin. The importance of bacteriology in dairy processes has now come to be so widely recognized that no student of dairying regards his training complete until he has had the fundamental principles of this subject. While this volume has now run through nine editions since it was first issued, the attempt has been made to keep it abreast of the times by revising it thoroughly when each edition has been printed. In this edition the volume has been wholly rewritten and practically re-illustrated.

Its aim is to furnish an outline of the subject, not an exhaustive treatise, but in sufficient detail to enable the general student of dairying to obtain as comprehensive an idea of the bacteria and their effects on milk and other dairy products as may be possible without the aid of laboratory practice. When possible the dairy student is urged to secure a laboratory knowledge of these organisms, but lacking this, the student and general reader should secure a general survey of the field of bacteriology in relation to dairying.

The growing importance of the subject of market milk has led to the introduction of an additional chapter on this subject.

H. L. R.
E. G. H.

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CHAPTER I.

STRUCTURE, GROWTH AND DISTRIBUTION.

Relation of bacteriology to dairying. The arts which have been developed by mankind have been the outgrowth of experience. Man first learned by doing, *how* to perform these various activities, and a scientific knowledge of the underlying principles which govern these processes was later developed.

The art of dairying has been practiced from time immemorial, but a correct understanding of the foundation principles on which the practice of dairying rests is of recent origin. In working out these principles, chemistry has been of great service, but in later years, bacteriology has been applied most successfully to the problems of modern dairying. Indeed, it may be said that the science of dairying, as related to the problems of dairy manufacture, is in large measure dependent upon an understanding of bacteriological principles. It is therefore essential that the student of dairying, even though he is concerned in large measure with the practical aspects of the subject, should acquire as complete an understanding of these principles as possible.

While bacteriology is concerned primarily with the activities of those microscopic forms of plant life known as the bacteria, yet the general principles governing the life of this particular class of organisms are sufficiently similar to those of other types of microscopic life that affect milk and its products to make it possible to include all of these types in a general consideration of the subject.

Nature of bacteria. The bacteria belong to the plant, rather than to the animal kingdom, although when they were first discovered, they were thought to be animals, because they had the power of motion. They are more nearly related to the fungi or colorless plants, than to the ordinary green plants, but at first glance, they do not appear to have many points in common with the smuts, mildews, and rusts, the most common and evident types of fungi. In structure, they possess with all other types of living matter, a definite form and shape. They are the simplest in structure of any of the plant types, the individual being comprised within the limits of a single cell. In this respect they differ from the larger forms of life which are many-celled and generally visible to the naked eye.

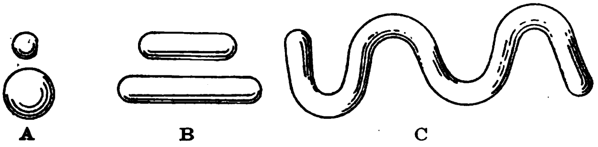

FIG. 1.—FORMS OF BACTERIA.
A, coccus; B, bacillus; C, spirillum.

Forms of bacteria. Every distinct type of life has a certain more or less well marked form which generally enables it to be distinguished from closely related types. With the many-celled plants and animals, the variation in form is naturally great, but with the single-celled type, like the bacteria and similar organisms, the possible variation in form and shape is obviously reduced.

In general, the bacteria may be grouped into three well-marked classes on the basis of their form. These are known as *coccus,* or round forms (plural cocci); *bacillus,* or rod-shaped forms (plural, bacilli); and *spirillum,* twisted types, (plural, spirilla). Of the types that are of significance in dairying, the bacilli and cocci are by far the most important.

Size of bacteria. The bacteria, as a class, are among the smallest of living objects. None of them are individually visible to the naked eye, and can be so seen only when clumps or masses are formed in the process of growth.

While there is considerable relative variation in size, yet in actual dimensions, this difference is so small as to make careful microscopic determinations necessary. An average diameter may be taken as about one thirty-thousandth of an inch, while the length varies naturally several fold, depending upon whether the type under observation is a coccus or a bacillus.

It is very difficult to conceive of the minuteness of the bacteria; the following may give some idea of their size. In a drop of cream ready for churning may be found as many as 10,000,000 and in a piece of fresh cheese as large as a cherry there may be as many living bacteria as there are people on our earth. While the bacteria are very minute, the work they do in milk and other dairy products is great, on account of their enormous numbers.

Manner of growth. The cells of which all plants and animals consist increase in numbers by the division of each cell into two cells through the formation of a division wall across the cell. The new cells divide and the plant or animal continues to grow. The single-celled bacteria increase in numbers in a similar way. In the case of those forms that have a greater length than diameter, the new wall is formed transversely to the long axis of the cell. As soon as the division is complete each cell is a complete individual, capable of carrying out all the processes necessary for the maintenance of its life. The cells may, however, cohere and thus form distinctive groupings that may serve to identify certain types. Some of the cocci form long chains and the term *streptococcus* is applied to such. Other groupings may be similar to a bale of twine or they may be massed in clusters with no regularity distinguishable.

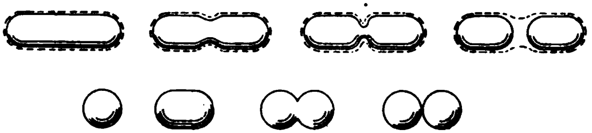

FIG. 2.—DIVISION OF BACTERIA.

The bacteria increase in numbers by the division of each cell into two cells. (After Novy.)

Spores. Just as ordinary plants form resistant structures, known as seeds, which contain the plant germ, capable of retaining its vitality under unfavorable growth conditions, thereby perpetuating the species, so with certain of the bacteria, definite cell structures, known as *spores,* that are analogous in some respects to the seeds of the higher plants, are produced within the mother cell. Such spores are exceedingly resistant to the influence of an unfavorable environment; in fact, toward heat, cold, drying, and even chemical agents, there are no more resistant organisms than some of the bacterial spores. It is this property which makes it so difficult to destroy effectively the bacterial life in the process of sterilizing milk. The property of spore-formation is fortunately confined to a comparatively small number of different species of bacilli.

Movement. Many of the bacteria are provided with vibratory organs of locomotion, known as *cilia* (singular, cilium) which are variously distributed on the surface of the cell. By the movement of these relatively long, thread-like processes, the cell is propelled through liquids. It must be remembered, when these moving cells are observed under the microscope, that their apparent rate of movement is magnified relatively as much as their size.

Conditions for growth. The bacteria, in common with all other living organisms are affected by external conditions, either favorably or unfavorably. Certain conditions must prevail before development can occur. Thus, the organisms must be supplied with an adequate and suitable food supply, and with moisture. The temperature must also range between certain limits, and finally, the oxygen requirements of the organism must be considered.

Food supply. Most bacteria are capable of living on dead, inert, organic matter, such as meats, milk, and vegetable material, in which case, they are known as *saprophytes.* In contradistinction to this class is a smaller group known as *parasites,* which derive their nourishment from the living tissues of animals or plants. The first group comprise by far the larger number of known organisms which are concerned in the decomposition of organic matter. The parasitic group includes those which are the cause of various communicable diseases. Between these two groups there is no sharp line of division and in some cases, certain species possess the faculty of growing either as parasites or saprophytes, in which case they are known as *facultative* parasites or saprophytes.

The great majority of bacteria of interest in dairying belong to the saprophytic class; only those species capable of infecting milk through the development of disease in the animal are parasites in the strict sense of the term. Most disease-producing species, as diphtheria or typhoid fever, while parasitic in man, lead a saprophytic method of life so far as their relation to milk is concerned.

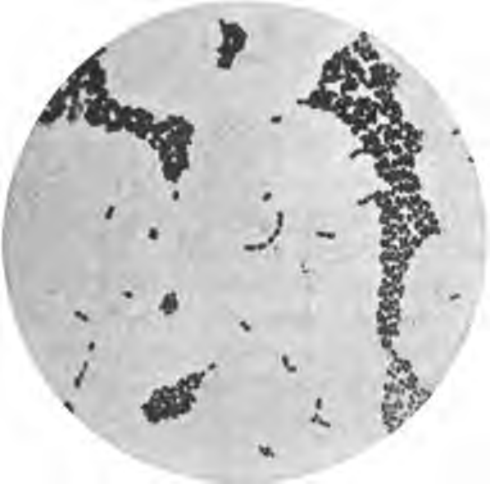

FIG. 3.—PHOTOMICROGRAPH OF LACTIC ACID BACTERIA.

Each cell is an individual organism. Magnified 1250 diameters.

Bacteria require for their growth nitrogen, hydrogen, carbon and oxygen, together with a limited amount of mineral matter. The nitrogen is most available in the form of organic compounds, such as albuminous material. Carbon in the form of carbohydrates, as sugar or starch, is most readily attacked by bacteria.

Inasmuch as the bacteria are plant cells, they must imbibe their food from material in solution. They are capable of living on solid substances, but in such cases, the food elements must be rendered soluble before they can be appropriated. If nutritive liquids are too highly concentrated, as in the case of syrups and condensed milk, bacteria cannot grow therein, although all the necessary ingredients may be present. Generally, bacteria prefer a neutral or slightly alkaline medium, rather than an acid reaction; but there are numerous exceptions to this general rule, especially among the bacteria found in milk. Meat broths or blood therefore putrefy, while plant tissues undergo mold development, since the acid reaction of plant juices favors the development of molds rather than bacteria.

Effect of temperature. Growth of bacteria can occur only within certain temperature limits, the extremes of which are designated as the *minimum* and *maximum.* Below and above these respective limits, life may be retained in the cell for a time, but actual cell-multiplication is stopped. Somewhere between these two cardinal temperature points, and generally nearer the maximum limit, is the most favorable temperature for growth, known as the *optimum.* The temperature zone in which growth of most dairy bacteria occurs ranges from 40° to 45° F. to somewhat above blood heat, 105° to 110° F., the optimum being from 80° to 95° F. Many parasitic species, because of their adaptation to the bodies of warm-blooded animals, generally have a narrower range, and a higher optimum, usually approximating the blood heat

(98° to 100° F). The broader growth limits of bacteria in comparison with other kinds of life explain why these organisms are so widely distributed in nature.

Oxygen supply. All living organisms require oxygen for combustion of food supplies and production of energy. Most bacteria require, as do the green plants and animal life, the free oxygen of the air for their respiration. These are called *aerobic.* Some species, however, and some yeasts as well, possess the peculiar property of taking from organic compounds, such as sugar, etc., the oxygen which they need, and are therefore able to live and grow under conditions where the atmospheric air is excluded. These are known as *anaerobic.* While some species grow strictly under one condition or the other, and hence are *obligate* aerobes or anaerobes, others possess the ability of growing under either condition, and are known as *facultative* or optional forms. The great majority of milk bacteria are either obligate or facultative aerobes.

Rate of growth. When there is an abundant supply of food and when the temperature conditions are favorable, the bacteria increase in numbers with astounding rapidity. It has been determined by actual experiment that the process of cell division under favorable conditions takes place in a few moments. Barber has shown that one of the forms of bacteria constantly found in milk will divide in 17 minutes at 98° F. and that a single organism kept at this temperature for ten hours had increased to 1,240,000,000. If the temperature is reduced to 50° F., the time required for division is increased to several hours. The explanation for the rapid spoiling of milk that is not well cooled is thus apparent. The initial rapid rate of increase cannot be maintained for any length of time as the conditions become more and more unfavorable as growth continues, due to the accumulation of the by-products of the cell activity. Thus, the growth of acid-forming organisms in milk becomes checked by the formation of acid from the fermentation of the sugar.

Detrimental effect of external conditions. Environmental conditions of a detrimental character are constantly at work tending to repress the activity of bacteria or to destroy them. These act more readily on the vegetating cells than on the more resistant spores. It is of the utmost importance that those engaged in dairy work be familiar with these antagonistic forces since it is constantly necessary to repress or to kill outright the bacteria in milk and other dairy products. In many lines of dairy work it is likewise important to be familiar with the conditions favorable for bacterial growth.

Effect of cold. While it is true that chilling largely prevents fermentative action, and actual freezing stops all growth processes, still it does not follow that exposure to low temperatures will effectually destroy the vitality of bacteria, even in the vegetative condition. Numerous non-spore-bearing species remain alive in ice for a prolonged period, and experiments with liquid air show that even a temperature of -310° F. maintained for hours does not effectually kill all exposed cells.

Effect of heat. High temperatures, on the other hand, will destroy any form of life, whether in the vegetative or latent stage. The temperature at which the vitality of the cell is lost is known as the *thermal death point.* This limit is dependent not only upon the nature of the organism, but upon the time of exposure and the condition in which the heat is applied. In a moist atmosphere, the penetrating power of heat is great, consequently cell death occurs at a lower temperature than in a dry atmosphere. An increase in time of exposure lowers the temperature point at which death occurs.

For growing organisms, the thermal death point of most species ranges from 130° to 140° F. for ten minutes. When spores are present, resistance is greatly increased, some forms being able to withstand steam at 212° F. from one to three hours. In the sterilization of milk, it is often necessary to heat for several hours, where a single exposure is made, to destroy the resistant spores, that seem to be more abundant under summer than winter conditions. Steam under pressure is a much more effective agent, as the temperature is thus raised considerably beyond the boiling point. An exposure of twenty minutes, at a temperature of 230° to 240° F. will kill all spores. Where heat is used in a dry state, it is much less effective, a baking temperature of 260° to 300° F. for an hour being necessary to kill spores.

Effect of drying. The spore-bearing bacteria withstand effects of desiccation without serious injury, and many of the non-spore-producing types retain their vitality for some months. The bacteria found in the air are practically all derived from the soil, and exist in the air in a dried condition, in which they are able to remain alive for considerable periods of time. In a dried condition, active cell growth is not possible, but when other conditions, such as moisture and food supply are present, resumption of growth quickly begins.

Effect of light. Bright sunlight exerts a potent germicidal effect on bacterial life, both in a spore and in a growing condition. Where the direct sunlight strikes, more or less complete disinfection results in the course of a few hours, the effect being produced by the chemical or violet rays, and not by the heat or red rays of the spectrum. This action, however, does not penetrate opaque objects, and is therefore confined to the surface. In diffused light, the effect is much lessened, although it is exerted to some extent. Sunlight exerts a beneficial effect on the general health and well-being of animal life, and is a matter of importance to be taken into consideration in the erection of buildings for animals as well as for people.

Effect of chemicals. A great many chemical substances exert a more or less powerful toxic action on various kinds of life. Many of these are of great service in destroying bacteria or holding them in check. Those that are toxic and result in the death of the cell are known as *disinfectants;* those that merely inhibit, or retard growth are known as *antiseptics.* All disinfectants must of necessity be antiseptic in their action, but not all antiseptics are disinfectants, even when used in large amounts. Disinfectants have no place in dairy work, except to destroy disease-producing bacteria, or to preserve milk for analytical purposes. The so-called chemical preservatives used to "keep" milk depend for their effect on the inhibition of bacterial growth. In this country, most states prohibit the use of these substances in milk. Their only function in the dairy should be to check fermentative and putrefactive processes outside of milk and so keep the air free from taints.

Products of growth. All bacteria, as a result of their growth in food substances, form more or less characteristic compounds that are known as *by-products.* The changes brought about are those of decomposition and are collectively known as *fermentations;* they are characterized by the production of a large amount of by-products as the result of the development of a relatively small amount of cell life. The souring of milk, the rotting of eggs, the spoiling of meats, the making of vinegar from cider are examples of fermentations caused by different bacteria.

If the substances decomposed contain but little sugar, as do animal tissues, the conditions are favorable for the growth of the putrefactive bacteria and foul-smelling gases are formed. When sugars are present, as in milk, the environmental conditions are most favorable for the acid-forming bacteria that do not as a rule produce offensive odors.

Many of the decomposition changes in organic matter occur only when such material is brought in direct contact with the living cell of the micro-organism. In other instances, soluble, non-vital ferments, known as *enzymes,* are produced by the living cell, which are able to act on organic matter, in a medium free from live cells.

Enzymes of these types are frequently found among the bacteria and yeasts, and it is by virtue of this characteristic that these organisms are able to break down such enormous quantities of organic matter. Most of these enzymes react toward heat, cold, and chemical poisons in a manner quite similar to the living cells. In one respect, they are readily differentiated, and that is, that practically all of them are capable of producing their characteristic chemical transformations under conditions where the activity of the cell is wholly suspended as under anaesthetic conditions in a saturated ether or chloroform atmosphere. The production of enzymes is not confined to bacteria, but they are found throughout the animal and plant world, especially in those processes that are concerned in digestion.

Distribution of bacteria. As bacteria possess greater powers of resistance than almost any other form of life, they are found very widely distributed over the surface of the earth. In soil they are abundant, because of the fact that all of the conditions necessary for growth are here best satisfied. They are, however, distributed with reference to the layers of the soil; the soil proper, i. e., that turned over by the plow, is extremely rich in them, on account of the abundance of organic matter. But at the depth of a few feet they decrease rapidly in numbers, and in the deeper layers, from six to ten feet, or more, they are normally not present, because of the lack of proper food supply and oxygen. The fertility of the soil is closely assoociated with their presence.

The bacteria are found in the air because of their development in the soil below. They are unable to grow even in a moist atmosphere, but are so readily dislodged by wind currents from the soil that over land areas the lower strata of the air always contain them. They are more numerous in summer than in winter; city air contains larger numbers than country air. Wherever dried fecal matter is present, as in barns, the air contains many forms.

Water contains generally enough organic matter in solution, so that certain types of bacterial life find favorable growth conditions. Water in contact with the soil surface takes up many impurities, and is of necessity rich in bacteria. As the rain water percolates into the soil, it loses its germ content, so that the normal ground water, like the deeper soil layers, contains practically no bacterial life. Springs, therefore, are relatively deficient in germ life, except as they become infected with soil organisms, as the water issues from the ground. Wells vary in their germ content, depending upon manner of construction, ease of infection at surface, etc. Wells are too frequently insufficiently protected from surface leachings, and consequently become infected with all kinds of organisms found in the surface soil. Typhoid fever is very frequently disseminated in this way, as is cholera and a number of animal maladies.

While the inner tissues of healthy animals are free from bacteria, the natural passages, as the respiratory and digestive tracts, being in more direct contact with the exterior, become readily infected. This is particularly true with reference to the intestinal tract, and in the undigested residue of the food, bacterial activity is at a maximum. The result is that fecal matter of all kinds contains enormous numbers of organisms so that the pollution of any food medium, such as milk, with such material is sure to introduce elements that seriously affect its quality.

CHAPTER II.

METHODS OF STUDYING BACTERIA.

Necessity of artificial cultivation. The bacteria are so extremely small, that it is impossible to study individual germs separately without the aid of powerful microscopes. Little advance was made in the knowledge of these lower forms of plant life until the introduction of culture methods, whereby a single organism could be cultivated, and the progeny of this cell increased to such an extent in a short course of time that the resulting mass of cells would be visible to the unaided eye. This is done by growing the bacteria on various kinds of food media that are prepared for the purpose, but inasmuch as bacteria are so universally distributed, it becomes an impossibility to cultivate any special form alone, unless the medium in which they are grown is first freed from all pre-existing forms of germ life.

Food materials. Culture media prepared from many different substances are employed in the bacteriological laboratory. In fact, bacteria will grow on almost any organic substance, whether it is solid or liquid, provided the other essential conditions of growth are furnished. The food substances that are used for culture purposes are divided into two classes,—solids and liquids.

Solid media may be either permanently solid, like potatoes and coagulated egg, or they may retain their solid properties only at certain temperatures, like gelatin or agar. The latter two are of utmost importance in bacteriological research, for their use, which was introduced by Robert Koch, permits the separation of the different forms of bacteria that may happen to be in any mixture. Gelatin is more advantageously used, because the majority of bacteria present wider differences, due to growth upon this medium, than upon any other. It remains solid at ordinary temperatures, becoming liquid at about 80° F. Agar, a gelatinous product derived from a Japanese seaweed, has a much higher melting point, and is used, especially with those organisms whose optimum temperature for growth is above the melting point of gelatin.

Besides these solid media, different liquid substances are extensively used, such as beef broth, milk and infusions of various vegetable and animal tissues. Skim milk is of especial value in studying the milk bacteria, and may be used in its natural condition, or a few drops of litmus solution may be added, in order to detect any change in its chemical reaction due to the bacteria.

Sterilization. The various ingredients that are used in the preparation of culture media are not free from micro-organisms, hence the media would soon spoil if they were not destroyed, and the media subsequently protected from contamination from the air, etc. The process of rendering the media free from living micro-organisms is known as *sterilization.* It may be accomplished in a number of ways but most often is done by the use of heat. For culture material, which is always organic in character, moist heat is employed. The various culture media, in appropriate containers, are subjected to a thorough steaming in a steam cooker. This destroys all of the vegetating cells but not the resistant spores that may be present. The media are then stored, for twenty-four hours, at temperatures favorable for the germination of the spores and are then again heated. Three such applications on successive days are usually sufficient to free the media from all living germs, since between the heating periods the spores germinate and the resulting cells are more easily destroyed. The sterile media will keep for an indefinite period in a moist place.

The media are usually placed in glass containers which may be sterilized before use by heating them in an oven, it being possible to thus secure a much higher temperature than with streaming steam. All glass or metal articles may be sterilized by the use of dry heat but for organic media, to avoid burning, moist heat must be used.

All kinds of materials may be sterilized by treatment with steam under pressure. An exposure for a few moments at 250° F., a temperature attained with 15 pounds steam pressure, will destroy all kinds of bacteria and their spores. This method of sterilization is used in the canning of meats and vegetables and in the preparation of evaporated milk. To avoid contamination of the media after sterilization, the flasks and tubes are, after being filled, stoppered with plugs of cotton-wool, which effectually filter out all bacteria and mold spores from the air, and yet allows the air to pass freely in and out of the containers.

Methods of isolation. The method of determining the number and kinds of bacteria in any substance can be illustrated by the process as applied to milk. For this purpose the method of procedure is as follows: Sterile gelatin in glass tubes is melted and then cooled until it is barely warm. To this melted gelatin a definite quantity of milk is added. The medium is gently shaken, so as to distribute thoroughly the milk particles, and is then poured into a sterile, flat, glass dish, and quickly covered, where it is allowed to cool, until the gelatin hardens. After the culture plate has been left for twenty-four to thirty-six hours at the proper temperature, tiny spots will begin to appear on the surface, or in the depth of the culture medium. These spots are called *colonies,* and are composed of an almost infinite number of individual cells, the result of the continued growth of a single organism that was in the drop of milk and which was firmly

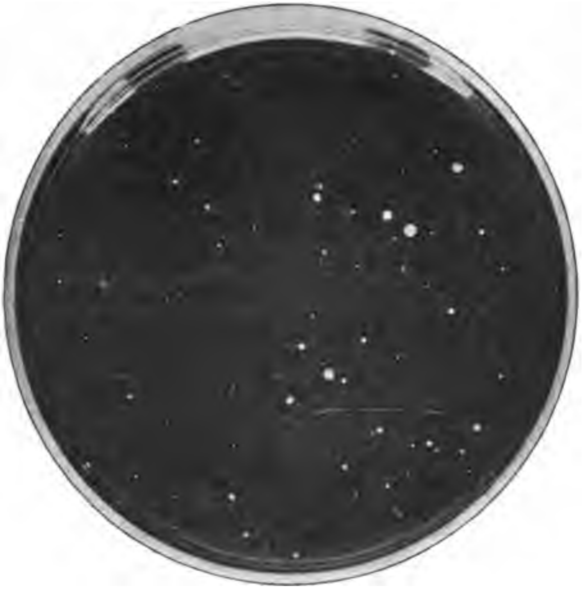

FIG. 4.—PLATE CULTURE.

Each of the dots is a colony that has been formed by the growth of an organism embedded in the solid culture-medium. By counting the colonies, the number of bacteria in the amount of milk added to the culture is determined.

held in place when the gelatin solidified. The number of these colonies represents approximately the number of bacteria that were present in the amount of milk added to the tube of gelatin. If the plate is not too thickly sown with the bacteria, the colonies will continue to grow and increase in size, and as they do, minute differences will begin to appear. These differences may be in the color, the contour, and the texture of the colony, or the manner in which it acts toward gelatin.

In order to make sure that the number of colonies is not so numerous as to prevent counting and continued study of their characteristics, an *attenuation* or *dilution* of the substance to be examined is usually made. This consists in adding a definite amount of the milk or other substances to a measured amount of sterile water, e. g., one cubic centimeter of milk to ninety-nine cubic centimeters of water. One cubic centimeter of this mixture may be used for the inoculation of the plate culture. This dilution may be carried on to any desired extent; in the examination of many dairy products, it is necessary to use very minute quantities of material, often only one one-millionth of a cubic centimeter. In practice a number of different dilutions are used, so that at least one plate shall contain such a number of colonies that it can be easily counted and studied.

To study further the peculiarities of the different bacteria, the separate colonies are transferred to tubes of sterile culture media. In order to do this the colony is touched with a piece of platinum wire; the minute amount of growth that adheres to the wire is sufficient to seed the tube of fresh culture medium. The inoculating needle must always be sterilized before use by passing it through a gas flame.

A culture thus obtained is called a *pure culture* since it contains but a single kind of an organism, as the colony is the result of the growth of a single cell. These cultures then serve as a basis for continued study, and must be planted and grown upon the different kinds of media that are obtainable. In this way the slightest variations in the growth of different forms are detected, and the peculiar characteristics are determined, so that the student is able to recognize this form when he meets it again.

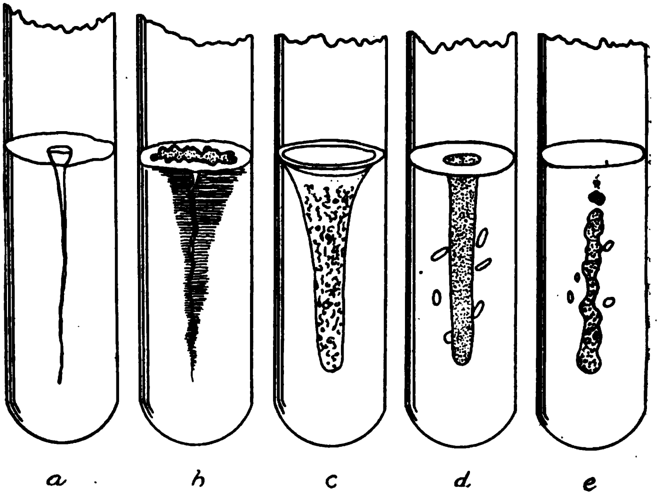

FIG. 5.—DIFFERENT KINDS OF BACTERIA GROWING IN GELATIN.

A, meager growth, no liquefaction or surface growth; B, profuse surface growth, radiating filaments from the growth below the surface; C, a rapid liquefying form; D, a gas producer that grows equally well in the presence or absence of air; E, form that grows only in the absence of air.

These culture methods are of essential importance in bacteriology, as it is the only way in which it is possible to secure a quantity of germs of the same kind.

The microscope in bacterial investigations. In order to verify the purity of the cultures, the microscope is in constant demand throughout all the different stages of the isolating process. For this purpose it is essential that the instrument used shall be one of strong magnifying powers (600 to 800 diameters), combined with sharp definition.

The microscopical examination of any germ is quite as essential as the determination of culture characteristics, in fact, the two must go hand in hand. The examination reveals not only the form and size of the individual germs but the manner in which they are united with each other, as well as any peculiarities of movement that they may possess.

In carrying out the microscopical part of the work, not only is the organism examined in a living condition, but preparations are made by using solutions of anilin dyes as staining agents. These are of great service in bringing out almost imperceptible differences. The art of staining has been carried to the highest degree of perfection in bacteriology, especially in the detection of germs that are found in diseased tissues in the animal or human body.

In studying the peculiarities of any special organism, not only is it necessary that these cultural and microscopical characters should be closely observed, but special experiments must be made in different ways, in order to determine any special properties that the germ may possess. Thus, the ability of any form to act as a fermentative organism can be tested by fermentation experiments; the property of causing disease, studied by the inoculation of pure cultures into experimental animals, like rabbits, guinea pigs and white mice. A great many different methods have been devised for the purpose of studying special characteristics of bacteria, but a full description of these would necessarily be so lengthy that in a work of this character they must be omitted. For details of this nature, consult standard reference books on bacteriological technique.

Incubation of cultures. The bacteria vary widely with reference to their optimum temperature for growth, hence, it is necessary for the successful growth of cultures in the laboratory to provide means by which the cultures can be incubated at the most favorable temperatures. Those most frequently maintained are 70° F. and 98° F. or approximately blood heat of the animal body.

CHAPTER III.

CONTAMINATION OF MILK.

Spoiling of milk. Materials of animal origin are peculiarly prone to undergo changes, rendering them unfit for use, and of these, milk is exceedingly susceptible to such changes. This is due to the fact that the composition of milk is especially adapted to bacterial growth, and that the opportunity for entrance of such organisms is likewise such as to permit of abundant infection. The consequence is that milk readily undergoes fermentation changes, due to the development of one type or another of micro-organisms.

Milk, a suitable bacterial food. While milk is designed by nature for the nourishment of mammalian life, it is, curiously enough, equally well adapted to the growth of these lowest forms of vegetable life. The nutritive substances required by bacteria are here sufficiently dilute to make possible rapid growth.

Milk also contains all the necessary chemical substances to make a suitable bacterial food supply. Of the nitrogenous compounds, albumen is in a readily assimilable form. Casein, the principal nitrogenous constituent of milk, exists in an insoluble condition, and cannot be directly utilized, until it is acted upon by digesting enzymes. The fat in milk does not readily decompose, and while there are a few bacteria capable of splitting up this substance, the majority of organisms are unable to utilize it. Milk sugar, on the other hand, is an excellent food for most species.

Sources of contamination. Inasmuch as milk is especially exposed to the inroads of bacterial growth, and because of the fact that much of the contamination can easily be prevented, it is highly important that the milk producer and dealer should be thoroughly cognizant of the various sources of contamination. The different factors concerned in contamination may be grouped as follows: the interior of the udder; utensils, including all apparatus with which the milk is brought in contact subsequent to withdrawal from the animal; infection coming from the animal herself, from the milker and the surrounding air.

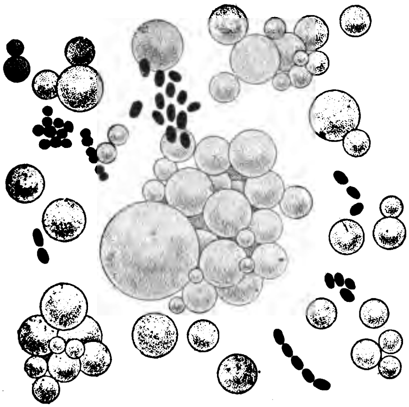

FIG. 6.—FAT GLOBULES AND BACTERIA.

Note the relative size of the fat globules of milk and the lactic acid bacteria.

Condition of milk when secreted. When examined immediately after withdrawal from the udder, milk always reveals bacterial life, yet in the secreting cells of the udder of a healthy cow, germ life does not seem to appear. Only when the gland is diseased are bacteria found in any abundance. In the passage of the milk from the secreting cells to the outside, it receives its first infection, so that when drawn from the animal it generally contains a considerable number of organisms.

A study of the structure of the udder shows the manner in which such infection occurs.

Structure of the udder. The udder is composed of secreting tissue *(gland cells)* that is supported by fibrous connective tissue. The milk is elaborated in these cells and is discharged into microscopic cavities, from whence it flows through the numerous channels *(milk sinuses)* that ramify through the substance of the udder, until finally it is conveyed into the *milk cistern,* a common receptacle holding about one half pint that is located just above the teat. This cavity is connected with the outside by a direct opening *(milk duct)* through the teat. During the process of milking, the milk is elaborated rapidly in the gland cells, and their contents, upon rupture of the milk cells, flow down into the cistern. The normal contraction of the muscles at the lower opening of the outer duct prevents the milk from passing out except when pressure is applied, as in milking. The inner walls of the milk duct and cistern are always more or less moist, and therefore afford a suitable place for bacteria to develop, if infection once occurs, and conditions are favorable for growth.

Manner of invasion. Two possible sources of invasion of the udder by bacteria may exist. If bacteria are present in the circulating blood, there is the possibility of organisms passing directly through the tissues into the milk-secreting cells. The other alternative is the possible direct contamination from the outside by organisms passing up through the milk duct, and so spreading through the open channels in the udder.

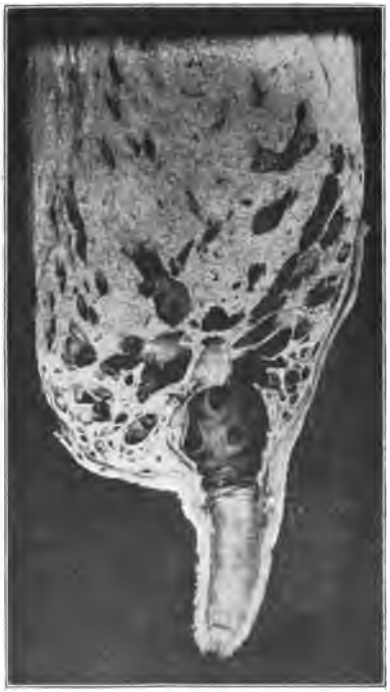

FIG. 7.—SECTIONAL VIEW OF UDDER.

Teat with milk duct connecting the exterior with the milk cistern. Milk sinuses which conduct the milk from the secreting tissue to the milk cistern. (After Moore & Ward.)

Number of bacteria in fore-milk. If a bacteriological examination is made of the milk drawn from each teat at different periods during the milking process, it will be found that the fore-milk, *i. e.*, the first few streams, contains, as a rule, many more organisms per cubic centimeter than that removed later. Not infrequently thousands of organisms per cubic centimeter may be found in the first streams while the middle milk, or strippings, will be quite free from them.

Distribution and nature of bacteria in udder. If the udder itself is carefully examined as to its bacterial content, it appears that the majority of organisms found is confined to the lower portion of this organ, in the teat, milk-cistern and large milk-ducts; while bacteria occur in contact with the secreting tissue, they are relatively less abundant. This would seem to indicate that the more probable mode of infection is through the open teat.

While there is no constant type of bacteria found in the fore-milk, yet it is noteworthy that nearly all observers agree that the organisms most commonly found are not usually the acid-producing, or gas-generating type, so abundant on the skin or hairy coat of the udder and which predominate in ordinary milks. Coccus forms, belonging to both liquefying and non-liquefying types are most generally present.

The bacteria coming from the interior of the udder are of small practical significance since they do not grow rapidly at the temperatures at which milk is stored. If the milk is protected from contamination due to other sources, those from the udder will ultimately cause it to spoil, but under ordinary conditions other forms are present in such greater numbers, and grow so much more rapidly in milk, that the udder forms have small opportunity to exert any effect.

It is interesting to note the bacteria found in the udder are similar to those that seem to be most abundant in such glandular tissues, as the liver and spleen, of apparently healthy animals. This fact increases the probability that these comparatively inert coccus forms of the udder may originate directly by filtration from the blood stream. The organisms that normally are found in the udder exert no harmful effects on the gland. It might be thought that due to the presence of abundant food and a favorable temperature that growth would be abundant, but such is not the case. At times the udder may be invaded by forms that are not held in check by the natural factors and an inflammation of the udder is likely to result.

Germicidal property of milk. It has been claimed that freshly drawn milk, like other body fluids, possesses germicidal properties, *i. e.,* the power of destroying bacteria with which it may be brought in contact. If milk is carefully examined bacteriologically, hour by hour, after it is withdrawn from the udder, it will generally be found that there is at first not only no increase in number of organisms during a longer or shorter period when it is kept at temperatures varying from 40° to 70°F, but that an actual reduction not infrequently takes place. When cultures of bacteria, such as *B. prodigiosus,* lactic acid organisms, and even the yellow liquefying coccus, so commonly found in the fore-milk, are artificially introduced into the udder, it has been found that no growth occurs and that in the course of a few days the introduced organisms actually disappear. Whether this failure to colonize can be regarded as evidence of a germicidal property or not is questionable. In fact, this question is a matter of but little practical importance in the handling of milk since under the best of conditions the keeping quality of the milk is not materially enhanced. It may be of importance in inhibiting growth in the udder.

Rejection of fore-milk. The fact that the fore-milk contains per cubic centimeter so much more germ life than the remainder of the milk has led some to advocate its rejection when a sanitary milk supply was under consideration. While from a purely quantitative point of view, this custom may be considered advantageous, in practice, however, it is hardly worth while since it is not at all certain that the rejection will have any effect on the keeping quality or healthfulness of milk. This is especially true if the ends of the teats are thoroughly cleaned before milking. It is true that the fore-milk is relatively deficient in fat so that the loss of butter fat occasioned by the rejection of the first few streams is comparatively slight.

Contamination from utensils. One of the most important phases of contamination is that which comes from the utensils used to hold the milk from the time it is drawn until it is utilized in one way or another. Not only is this important because it is a leading factor in the infection of milk, but because much improvement can be secured with but little trouble, and it is especially necessary that the dairy student should be made familiar with the various conditions that obtain. Pails and cans used to hold milk may be apparently clean to the eye, and yet contribute materially to the germ content of milk. Not only does much depend upon their condition, but it is equally important to take into consideration their manner of construction. Dairy utensils should be simple in construction, rather than complex. They should be made so that they can be readily and easily cleaned, or otherwise the cleaning process is apt to be neglected.

Of first importance are those utensils that are used to collect the milk and in which it is handled while on the farm. The warm milk is first received in pails, and unless these are scrupulously cleaned, an important initial infection then occurs. As ordinarily washed, the process falls far short of ridding the utensils of bacterial life that is adherent to the inner surface of the pail. Then, too, all angles or crevices afford an excellent hiding place for bacteria, and it is very important to see that all seams are well soldered. Round corners and angles greatly facilitate thorough cleaning of utensils. Tin utensils are recognized as most satisfactory.

Shipping cans are likely to serve as greater infecting agents than pails for they are subject to more wear and tear and are harder to clean. As long as the surface is bright and smooth, it may be easily cleaned, but large utensils, such as cans, are likely to become dented and rusty in spots on the inner side. The storage of milk in such utensils results in its rapid deterioration. The action of rennet has been found to be greatly retarded where milk comes in contact with a rusty iron surface. It is equally important that attention be paid to the care of strainers, coolers, and the small utensils. Cloth strainers are more or less of a hotbed for bacterial growth, for unless they are boiled, and then dried quickly and thoroughly, germ growth will continue apace in them, as long as they contain any moisture.

Milking machines and farm separators. The introduction of these special types of dairy machinery in the handling of milk on the farm has materially complicated the question of care of milk. Both of these types of apparatus are much more complicated than the usual milk utensil; consequently, the danger of imperfect cleaning is thereby increased. This is still further accentuated by the fact that cleansing of utensils on the farm can never be done so easily as at the factory where steam is available. The milking machine may be easily kept in a comparatively germ-free condition, but unless this is done, it contributes its quota of germ life to the milk. The farm separator is more widely used and in actual practice, the grossest carelessness prevails in the matter of its care. Frequently, it is only rinsed with water, and is not taken apart and thoroughly cleansed. So long as it remains moist, bacterial growth can go on, and as it is generally handled on the farm, it serves to infect the milk. The widespread introduction of the hand separator has probably contributed more to lower the quality of cream delivered at the factory than any other single factor.

Infection from factory by-products. The custom of returning factory by-products in the same set of cans that is used to bring fresh milk is a prominent cause of bad milk. Whey and skim milk are rich in bacterial life, and not infrequently are so handled as to become a foul, fermenting mass. If the cans used to transport this material are not scrupulously cleaned on the farm, transfer of fermentative bacteria to the milk is made possible. In this way the carelessness of a single patron may be the means of seeding the whole factory supply. This custom is not only liable to produce a poor quality of milk, but it is more or less of a menace to all the patrons of a factory, inasmuch as the opportunity always obtains that infectious disease germs may thus be introduced into the supply. Not infrequently is tuberculosis thus spread through the medium of factory by-products.

The manufacture of Swiss cheese presents a striking example of the disregard which factory operators show toward the employment of bacteriological principles. In these factories, the custom is widely practiced of apportioning the patrons' allotment of whey into individual barrels which are supposed to be emptied each day. As these barrels are however rarely ever cleaned from the beginning to the end of the season, they become very foul, and the whey placed in them from day to day highly polluted. It is this material which is taken back to the farms in the same set of cans that is used for the fresh milk. When one recalls that the very best type of milk

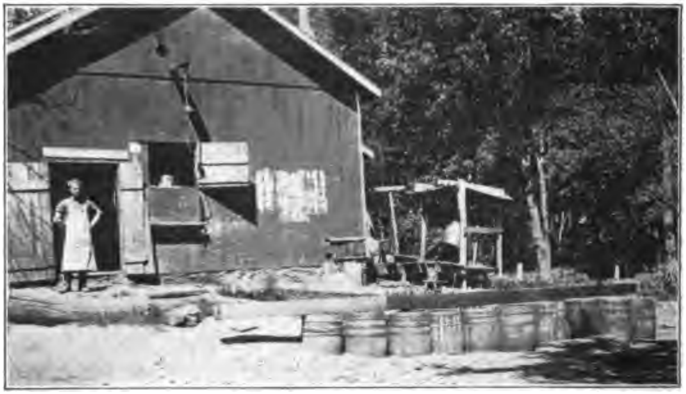

FIG. 8.—WHEY DISPOSAL.

Whey barrels at a Wisconsin Swiss cheese factory. Each patron's share is placed in a barrel which is so situated that it is impossible to empty it completely; thus it is not cleaned during the season.

is essential for the making of a prime quality of Swiss cheese, and that to secure such, the maker insists that the patron bring the product to the factory twice daily, the before mentioned practice appears somewhat inconsistent.

Treatment of factory by-products. To overcome the danger of infecting milk from factory by-products with either undesirable fermentative organisms, or disease-producing bacteria, the most feasible process is to destroy these organisms by the application of heat. In Denmark, some portions of Germany, and in some of the states in this country, compulsory laws exist which require the heating of all skim milk before it is returned to the farm. This is done by the direct use of exhaust steam, or running the product through heaters.

The treatment of whey in cheese factory practice is especially important since the warm whey must be stored for a number of hours before it is returned to the farms. Even under the best of conditions the whey is certain to be in an advanced state of fermentation when placed in the milk cans, and it only needs the infection of the whey tank with harmful bacteria to cause great loss on account of the injury of the product by these bacteria. Among Canadian factories the custom of heating the whey as it passes from the cheese vat to whey tank has been introduced, and where ever adopted has been retained, because it has resulted in such an improvement of the cheese that the gain was much greater than the cost, which is estimated at not over fifty cents per ton of cheese. The whey is heated to 140° F.; the hot whey serves to scald the whey tank and as the mass of whey is usually quite large, it does not cool to a point where bacterial growth can take place for a number of hours.

The whey is thus quite sweet when returned to the farm and has greater feeding value. The heating also prevents the creaming of the whey in the tank and thus avoids the soiling of the cans with grease which is most difficult to remove.

Where compulsory legislation is in force it is generally required that this material be heated to a temperature of at least 176° F. This is done so as to destroy effectually the organisms of tuberculosis, and especially to permit of the utilization of the so-called Storch test,[1] which enables a person to determine quickly whether milk or whey has been heated or not.

Cleaning utensils. Various processes are applied to dairy utensils to cleanse them. In removing visible dirt and foreign matter, much of the bacterial life is mechanically eliminated, but most of the cleaning processes fail to destroy the germ life in these utensils.

In rinsing, washing, or even scalding, the water is not applied at a sufficiently high temperature to destroy effectively the bacteria. These processes are primarily used for the removal of dirt and other matter. To facilitate such removal, washing powders of various kinds are frequently employed; some of these possess considerable disinfecting action. All utensils after cleansing should be thoroughly rinsed in clean hot water. Even where no further treatment is given, a careful cleaning may so reduce the germ content on the inner surface of utensil as to render contamination relatively unimportant. Most of the contamination in a well cleaned utensil comes from the cracks and angles, which permit of the collection of the dirt. If these are properly attended to, thorough cleaning and rinsing alone will accomplish much.

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[1] Storch (40 Rept. Expt. Stat., Copenhagen, 1898) has devised a test whereby it can be determined whether this treatment has been carried out or not; milk contains a soluble enzyme known as peroxidase which has the property of decomposing hydrogen peroxid. If milk is heated to 176° F., (80° C.) or above, this enzyme is destroyed, so that the above reaction no longer takes place. If potassium iodid and starch are added to unheated milk and the same treated with hydrogen peroxid, the decomposition of the latter agent releases oxygen which acts on the potassium salt, which in turn gives off free iodine that turns the starch blue.

To exert an actual germ-destroying effect on the bacterial content of the utensil, resort must be had to boiling or steaming. To sterilize thoroughly utensils so as to render them wholly germ-free would be impractical under ordinary commercial conditions, as it would consume too much time, although with proper apparatus, this process is not impossible, but it is well within the limits of practicability in factory treatment to apply steam for a short period of time. Where cans, pails and such utensils, are steamed for a minute or so after being thoroughly cleaned, the germ content is greatly reduced. In a series of tests by Harrison, the germ content of a set of cans cleaned in an ordinary way was 442,000 bacteria per cubic centimeter in 100 cubic centimeters of wash water; in a set washed in tepid water and then scalded—the best farm practice—it was 54,000 per cubic centimeter, while in cans carefully washed and then steamed for 5 minutes, it was reduced to 880 per cubic centimeter. It would not be worth while to institute measures that would accomplish the destruction of this small residual content.

The use of steam, therefore, is of great service in eliminating bacterial life in all utensils. In apparatus of at all complicated design, it is absolutely necessary. Of course, ordinarily, steam can be applied only at the factory, as the farm does not usually afford facilities for its easy generation. This fact has led in some cases to the adoption of the method of cleaning and sterilizing the cans at the factory rather than to await their arrival at the farm. This custom is most frequently followed in milk supply plants.

It is also very important in cleaning dairy utensils to see that they are rapidly and thoroughly dried after being washed and steamed. As pointed out above, the short period of steaming that can be followed in practice does not kill all the bacteria. If moisture is retained, conditions permit of the growth of the undestroyed organisms. Tests made on glass milk bottles showed that considerable growth occurred in the condensation water even after quite thorough sterilization. Other utensils such as cloth strainers become sources of bacterial infection unless the articles are thoroughly and quickly dried after cleaning.

In a general way, it may be said that whenever a utensil is so constructed and in such a condition that every portion of its surface can be reached by a cloth or a brush, it can be kept in a sanitary condition. But whenever any portion cannot be thus reached, whether it is an angle or a seam in a pail or can, the interior of the separator bowl, or in the pipes used in conducting milk, contamination is certain to result from such places, unless extreme care is taken to destroy the bacteria therein by steaming.

Contamination from the animal. In the process of milking, the bacterial content of the milk is materially increased. In part this comes from the utensils into which the milk is drawn, but the animal herself, the milker, as well as the surrounding air, also contribute to a varying extent. Of these factors, the one fraught by far with the most consequence, is the influence of the animal herself. It is a popular belief that the organisms found in milk are derived from the feed and water which the animal consumes, but under normal conditions, the bacteria consumed in food pass through the intestinal canal and do not appear in the circulation. It must not be assumed, however, that the character of feed and water supply is of no moment. Stock should be given pure and wholesome water and no decomposed or spoiled food should be used.

The infection traceable directly to the cow is modified materially by the conditions under which the animal is kept and the character of the feed consumed. The nature of the fecal matter is in part dependent upon the character of the food. The more nitrogenous the ration fed, the softer are the fecal discharges, producing a condition which is more likely to soil the coat of the animal unless care is taken. The same is true with animals kept on pasture in comparison with those fed dry fodder.

Stall-fed animals, however, are more likely to have their flanks fouled, unless special attention is paid to the removal of the manure. All dairy stalls should be provided with a manure drop which should be cleaned as frequently as circumstances will permit.

The animal contributes materially to the quota of germ life finding its way into the milk through the dislodgment of dust and filth particles adhering to its hairy coat. The nature of this coat is such as to favor the retention of these particles. Unless care is taken, the flanks and udder become polluted with fecal matter, which upon drying is displaced with every movement of the animal. Every hair or dirt particle so dislodged and finding its way into the milk-pail adds its quota of organisms to the liquid. This can be readily demonstrated by placing cow's hairs collected with care on the moist surface of gelatin culture plates. Almost invariably bacteria will be found in considerable numbers adhering to such hairs, as is indicated in Fig. 9.

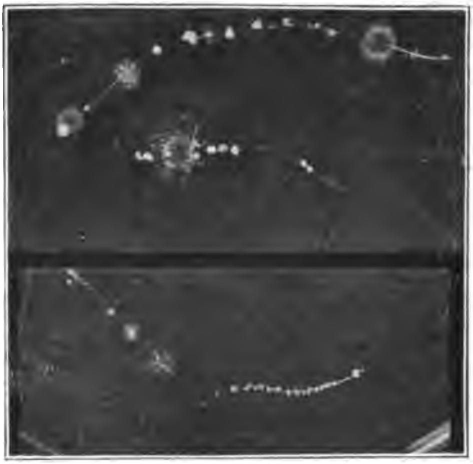

FIG. 9.—BACTERIA ON HAIRS.

Each colony on the hair represents one or more bacteria that were adherent to the hair when it was placed on the surface of the solid culture-medium.

Dirt particles are even richer in germ life. Not only is there the dislodgment of hairs, epithelial scales, and masses of dirt and filth, but during the milking process, as at all other times, every motion of the animal is accompanied by a shower of *invisible* particles, more or less teeming with bacterial life. All of this material contains organisms that are more or less undesirable in milk.

Bacteria concerned in gassy fermentations and those capable of producing obnoxious taints are particularly common, so that this type of pollution is especially undesirable in milk.

Amount of dirt in milk. When one remembers that about one-half of fresh manure is soluble in milk, and thus does not appear as sediment, the presence of evident filth in milk must bespeak extremely careless methods of handling.

The sediment or dirt test used quite extensively in Germany and Denmark is employed to ascertain the amount of dirt milk may contain. By means of a cotton filter, the insoluble residue is concentrated, and is made evident upon a layer of absorbent cotton. Milk that would show with difficulty any evidence of dirt upon ordinary examination reveals such defects very readily in this test.

Exclusion of dirt. It is better to keep bacteria out of milk, so far as practicable, rather than to attempt to remove them after they have once gained entrance. As is usual, prevention of trouble is much more easily accomplished than removing the difficulty after it once occurs.

Much reduction as to the amount of dirt that finds its way into milk may be accomplished by improved stable environment. The fouling of the udder and flanks comes from wading in slime infected water, dirty yards, and improper type of stables. Barnyards are often a disgrace through the accumulation of manure and seepage. Cows wading in such mire cannot but accumulate mud and filth to a material degree on the teats and udder. Greater care as to drainage of the barnyard and the paving of same with gravel will permit of its being kept clean, and so prevent the fouling of animals. But more important than the yard is the stall which the animal occupies in the stable. The essential feature is to have a stall of such construction as to keep the animal out of her own manure when she lies down. To accomplish this, it is necessary to have a manure drop behind the stall proper

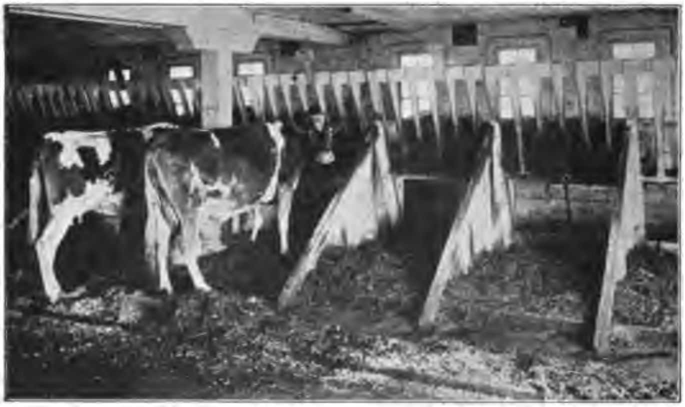

FIG. 10.—THE MODEL STALL.

A stall of this type keeps the animals clean, and thus aids greatly in producing good milk.

so that the feces and urine are kept out of the bed of the stall as much as possible.

Most of the stalls widely advertised in the farm press seek to accomplish this in one way or another, usually by some arrangement by which the cow is forced back when standing and drawn forward on lying down. In Fig. 10 a type of stall is illustrated that accomplishes this most successfully; the essential feature being a 2x3-inch wood strip nailed to the stall floor immediately in front of the hind feet of the animal when in a standing position. When animal lies down, she crowds forward to avoid lying on this strip, and thus is out of contact with the manure, except such as is tracked onto the bedding by the hind feet. By the use of this stall it is possible to keep the animals free from all accumulations of manure.

Effort should be made to prevent fouling of the animals rather than in cleaning them after once soiled. It is very evident that where the cattle come to the milker with muddy udders, they will not be so cleaned before milking as to prevent a large amount of such dirt from entering the milk. However, when all that can be done towards keeping the cows clean has been accomplished, a small amount of grooming will greatly reduce the contamination coming from them.

The kind of bedding used in the stalls may have a marked influence on the contamination coming from the animal. If the straw is dusty, partially rotten and moldy, the bacteria and molds adhere to the coat of the animal and are thus introduced into the milk. In the case of cattle on pasture, no visible evidences of dirt are usually present but the hair is covered with the dust coming from the soil. There is very good reason to believe that the quality of milk is influenced by the type of pasture on which the cows graze, due to the difference in the types of bacteria in the surface soil. The milk from animals on low land is more likely to show undesirable fermentations than that from those grazing on higher lands. This is not due to the influence of the feed as is often supposed but rather to the dirt from the coat of the animal.

Washing the udder. If a surface is moist, dust and the adherent bacteria cannot be easily dislodged. The air over snow-covered mountains or over oceans is relatively free from bacteria. The udder and flanks of the animals can be carded to remove the loose hairs and the evident dirt; the fine dust can now be removed by wiping with a clean damp cloth just before the milking process. The actual washing and wiping of the udder and flanks still further reduces the contamination coming from the animal; experiments show a reduction of fully three-fourths of total contamination. Clipping the udder and flanks also aids in keeping the animal clean. Tests made show that the germ content of the milk in the pail is frequently increased from animal directly from 20,000 to 40,000 bacteria *per minute* during the milking period.

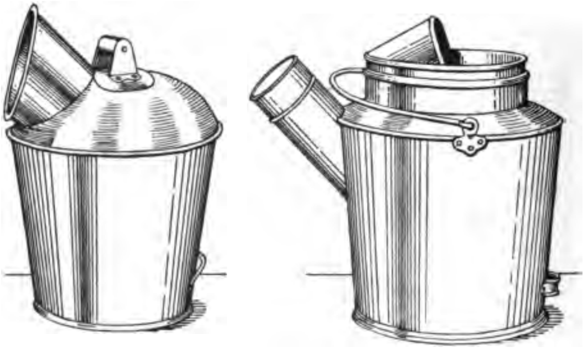

FIG. 11.—SANITARY MILK PAILS.
The small opening is very efficient in keeping the dirt out of milk.

It is often asserted that the treatment of the animals in these ways reduces the yield of milk. It is certain that such an effect will persist for only a short time and there is reason to believe that grooming increases the yield.

Sanitary milk pails. The entrance of organisms into the milk can be greatly reduced by lessening the area of the milk pail exposed to the dust shower. To accomplish this purpose a number of so-called sanitary or hygienic milk pails have been devised. In some cases, these are the regular type of pail provided with a cover having a small opening through which the milk is received. In other cases, a strainer is interposed so as to remove more effectually the coarse particles. While pails of this type are successful in the removal of a large part of the dirt, and consequently reduce materially the bacterial content of the milk, yet they must be of simple construction, so that they can be kept in a clean condition in order to adapt them for general practical use. The use of such a utensil increases materially the keeping quality of the milk.

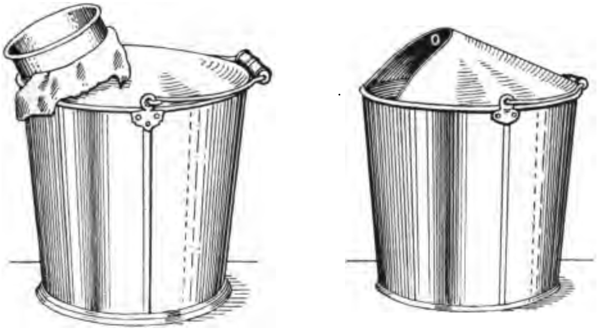

Fig. 12.—Sanitary Milk Pails.

The Stadtmueller pail and the Truman pail, two of the most practical of the small-topped pails.

Stocking has shown that under ordinary barn conditions, the use of small-topped pails reduced the number of bacteria 95 per cent; with dirty cows the reduction in bacteria amounted to 97 per cent. A six-inch opening presents only one-fourth as large an exposure as a twelve inch, so that the reduction in bacterial content is greater than the lessening in the size of the openings of the pails. The ordinary pail receives dust not only from the udder, but also from the flank which is usually a more important source of contamination than the udder itself, while the small-topped pail receives only that from the udder.

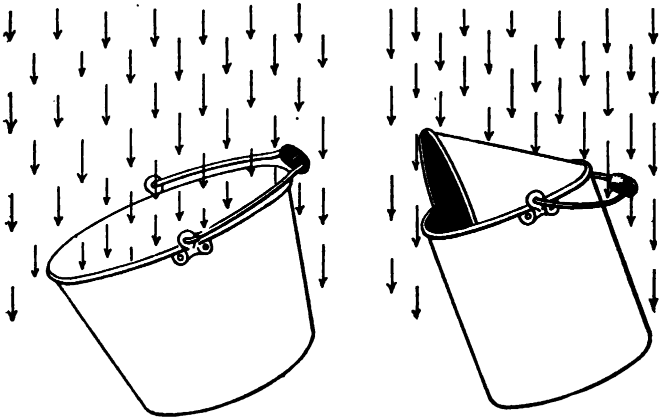

FIG. 13.—USE OF SANITARY MILK PAILS.

The open pail is fully exposed to the falling dust while the hooded pail excludes much of the dust and dirt coming from the animal.

Milking machines. Where the milk is removed from the udder by machine methods, instead of by hand, it is possible to eliminate nearly all external contamination from the animal and her surroundings. The only opportunity for infection is then through the leakage of air around the teat cups. Care should be taken to see that the teats are in a clean condition before applying the suction cups. The main problem in the use of a milking machine is to keep the apparatus in an aseptic condition. Immersion of the teat cups and the rubber connections in lime water, brine solution, or other mild antiseptics, prevents bacterial development. Hastings has found that milk having a germ content of less than 10,000 bacteria per cubic centimeter may be produced by the use of a properly handled milking machine.

Contamination from the milker. While the milker is a small factor in comparison with the animal in the matter of contamination, yet he can not be neglected, as it is within his power to affect profoundly the quality of the milk. His personal habits as to cleanliness and his appreciation of the precautions necessary in the production of clean milk have much to do with the contamination of the milk. The milking should be done with dry hands, although a little vaseline may be used with effect. The hands should be washed before milking as milk is certain to come in contact with them to some extent. The milking should be done with the whole hand rather than stripping between the thumb and finger; the clothing should be covered with clean overalls and jumper, or at least a clean apron should be worn during the milking. If these are of white material, more frequent laundering is likely to result.

Contamination from air. It is difficult to disassociate the contamination arising from the condition of the air from that derived directly from the animal. Barn operations of various kinds result in the production of dust, particularly where dry forage, such as hay or straw, is handled. Where manure is given an opportunity to dry, dust is readily produced, and such material is particularly replete with bacterial life. Some kinds of dust, such as that originating from ground grains, or shavings that may be used for bedding, contain a small amount of bacterial life in comparison with hay. In a dried condition, the slightest movement is apt to dislodge these fine particles, and they float in the air for considerable periods of time. If milk is drawn and exposed to the air of the barn during the feeding operations, it is subject to the dust shower that is present. Where the

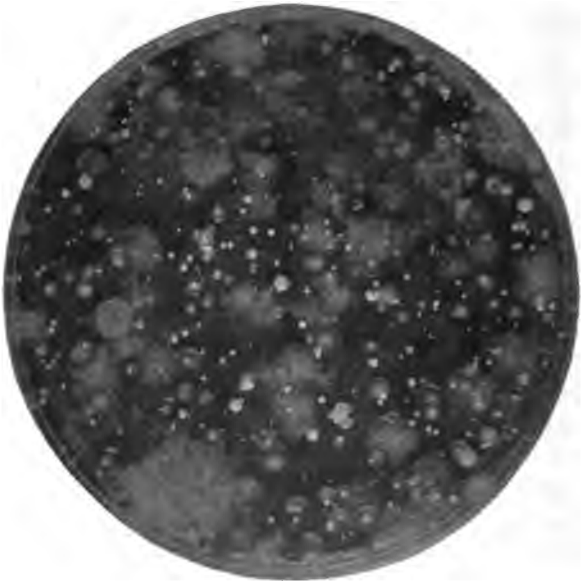

FIG. 14.—CONTAMINATION FROM THE AIR.

This culture plate, three inches in diameter, was exposed for 30 seconds in the barn during feeding of dry fodder. A 12-inch pail exposes over 15 times the surface of this plate.

storage can is allowed to stand in the stable during the milking, even though it is covered with a strainer, this accumulation of microscopic particles is added to the milk, as they readily pass the meshes of the finest strainer.

Removal of dirt after introduction. The more primitive method of improving the quality of milk, so far as its dirt content is concerned, is to attempt to remove the grosser particles of contamination after entrance. In the case of straining, the method is usually applied at the time of milking, but in the case of filtering and clarifying, it is carried out at the milk station, in an effort to improve the appearance of milk, and overcome the influence of careless methods of the producer. By the use of strainers, either metallic or cloth, it is possible to remove particles of hair, undissolved dirt, and manure, but it must be remembered that these grosser *visible* particles of pollution are not really the cause of the troubles which may ensue in improperly handled milk. The bacteria which are adherent to these foreign particles are in large measure washed off in the process of straining, and pass through the meshes of the finest strainer. The main service, therefore, of straining is to improve the appearance of the milk, and it has no effect on the quality in any way.

Production of clean milk. The problem of clean milk is important, whatever may be the use to which milk may be put. It is important in the manufacture of butter, but owing to the fact that the fat is not readily acted upon by bacteria, it is not so sensitive to bacterial conditions, as when the milk is made into cheese. In this product, the bacterial condition of the milk is a matter of prime importance. In milk destined for direct consumption, the exclusion of the bacteria becomes yet more important. While it is impossible to exclude bacteria so completely that milk will not undergo fermentative changes, yet for domestic consumption it is preferable to have milk with as low bacterial content as can readily be secured. The highest type of market milk, that known as sanitary, or certified, is produced under such extreme conditions of care as to contain the minimum germ content. To accomplish these results requires such stringent control as to increase greatly the cost of the product. Pure, clean milk can be produced at a very slight increase in cost over the regular expense of milk production, if the right kind of attention is given to certain details of a practical character. Improvement in our milk supplies must largely come from this source, for any improvement to be permanent must be made to pay, and it requires considerable education to secure the co-operation of consumers and their willingness to pay for any material increase in the quality of the product.

In the foregoing factors concerned in the contamination of milk, it is of course impossible to measure accurately the influence of the different sources of infection, as these are continually subject to variation in every case. As a rule, the most important factors are those pertaining to the utensils and the condition of the animal herself. If these two factors are brought under reasonable control, the major portion of contamination that ordinarily obtains is done away with. The application of the remedial or preventive measures heretofore mentioned will greatly reduce the germ content of the milk.

Cooling of milk on farm. Bacterial growth is directly related to temperature conditions, and with summer temperatures, such development goes on apace, unless it is checked by early cooling. The larger portion of bacteria that find their way into milk, especially those that are previously in contact with the air, are in a semi-quiescent condition, and are therefore not stimulated into immediate growth, unless reasonably high temperatures prevail. In milk, which comes from the animal at blood heat, this growth is greatly stimulated. To counteract this effect, milk should be chilled as soon after milking as possible. If the temperature is immediately lowered to 50° F., or lower, actual cell development is greatly retarded, and the rate of souring, and other fermentative changes thereby diminished. In this country ice is liberally used in accomplishing this result. In Europe, the use of ice is much less common. The employment of such artificial means of refrigeration makes possible the shipment of milk for long distances by rail. New York city now receives milk that is produced in Canada and northeastern Ohio.

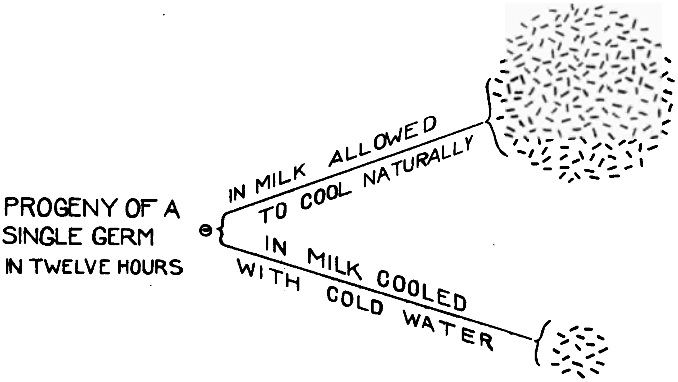
PROGENY OF A SINGLE GERM IN TWELVE HOURS
IN MILK ALLOWED TO COOL NATURALLY
IN MILK COOLED WITH COLD WATER

FIG. 15.—EFFECT OF COOLING MILK.

Aeration of milk. The custom has been extensively recommended of subjecting milk to the influence of air in the belief that such exposure permits of the interchange of gases that would improve the quality. In practice, this process, known as aeration, is carried on in different ways. In some cases, air is forced into the milk; in others, the milk is allowed to distribute itself in a thin sheet over a broad surface, falling in drops or tiny streams through the air. Whenever this process is carried on at a temperature lower than that of the milk, it results in more or less rapid cooling.

In earlier times, aeration was generally recommended and practiced, especially in connection with the cheese industry, but carefully controlled experiments fail to show that the process exerts any material influence on the rate of germ development. If it is carried out in an atmosphere more or less charged with bacteria, as in the barn or stable, it is more than likely to add to the bacterial content of the milk. While to some extent odors may be eliminated by the process, the custom is not followed so generally now as it used to be some years ago.

Absorption of taints. A tainted condition in milk may result from the development of bacteria, acting upon various constituents of the milk, and transforming these in such a way, as to produce by-products that impair the flavor or appearance of the liquid; or it may be produced by the milk being brought in contact with any odoriferous or aromatic substance, under conditions that permit of the direct absorption of such odors.

This latter class of taints is entirely independent of bacterial action, and is largely attributable to the physical property which milk possesses of absorbing volatile odors. This direct absorption may occur before the milk is withdrawn from the animal, or afterwards if exposed to strong odors.

It is not uncommon for the milk of animals advanced in lactation to have a more or less strongly marked odor and taste; sometimes it is apt to be bitter, at other times salty to the taste. It is a defect that is peculiar to individual animals, and is liable to recur at approximately the same period in lactation. The peculiar "cowy" or "animal odor" of fresh milk is an inherent peculiarity that is due to the direct absorption of volatile elements from the animal herself.

Many kinds of feed consumed by the animal produce a more or less pronounced taint or flavor in the milk. With some plants, such as garlic, leeks, turnips, and cabbage, the odor is so pronounced as to render the milk quite unfit for use. In some states along the Atlantic seaboard, wild plants of this character in woodland pastures may be so abundant as to make it impossible to pasture milch animals. The difficulty in such cases is due to absorption of the volatile principles into the circulation of the animal, and if such feed is consumed shortly before milking, the characteristic odors appear in the milk. If consumed immediately after the milk is withdrawn from the animal, sufficient time may elapse so that the peculiar odors are dissipated before the milk is again secreted. The same principle applies in a lesser degree to the use of certain green fodders that are more suitable for feed, such as rape, green rye, or even silage. Silage produces a distinct, but not unpleasant odor in milk, but newly pastured rye often confers so strong an odor as to render the milk unusable.

Where certain drugs are employed in the treatment of animals, such as belladonna, castor oil, sulfur, or turpentine, the peculiar odors may reappear in the milk. Such mineral poisons as arsenic have been known to persist for a period of three weeks before elimination.

On account of the elimination of many drugs, unchanged, from the animal in the milk, the milk of any animal that is receiving medicine should not be used for human food. When such milk is mixed with that of a number of other animals and when it is used by adults, no harm is likely to result, but when the dilution is not great and the milk is used for young children it may affect them through its content of the drug. The feed may not only affect the quality of milk but its value as food. One of the most prominent of American dairymen, who has for many years produced milk especially for children's use, has said that he could feed his cows so as to make ill every child receiving the milk.

Absorption of odors after milking. If milk is brought in contact with strong odors after being drawn from the animal, it will absorb them readily, as in the barn, where frequently it is exposed to the odor of manure and other fermenting organic matter.

It has long been a popular belief that milk evolves odors and cannot absorb them so long as it is warmer than the surrounding air, but from experiments of one of us (R), it has been definitely shown that the direct absorption of odors takes place much more rapidly when the milk is warm than when cold, although under either condition, it absorbs volatile substances quite rapidly.

The custom of straining the milk in the barn has long been deprecated as inconsistent with proper dairy practice, and in the light of the above experiments, an additional reason is evident why this should not be done.

Even after milk is thoroughly cooled, it may absorb odors, as is noted where the same is stored in a refrigerator with certain fruits, meats, fish, etc.

Distinguishing bacterial from other taints. In perfectly fresh milk it is relatively easy to distinguish between taints caused by the growth of bacteria and those attributable to direct absorption. If the taint is evident at time of milking, it is in all probability due to character of feed consumed, or possibly to medicines. If, however, the intensity of the taint grows more pronounced as the milk becomes older, then it is probably due to living organisms which require a certain period of incubation before their by-products are most evident.

Moreover, if the difficulty is of bacterial origin, it can be frequently produced in another lot of milk (heated or sterilized is preferable) by inoculating the same with some of the original milk. Not all abnormal fermentations are able, though, to compete with the lactic acid bacteria, and hence outbreaks of this sort soon die out by the re-establishment of more normal conditions.

Factory contamination. As the time element is of importance in the production of troubles due to bacteria, it follows that infection of the milk on the farm is fraught with more consequence than factory contamination, as the organisms introduced would have a longer period of development. Nevertheless, the conditions in the factory are by no means to be ignored, as they not infrequently permit the milk to become seeded with highly undesirable types. A much more rigid control can be exercised in the factory, where steam is at hand as an aid in the destruction of organisms. In the cleaning of pumps and pipes, steam is absolutely necessary to keep such apparatus in a sanitary condition.

The water supply of the factory is a matter of prime importance, as water is used so extensively in all factory operations. When taken from a shallow well, especially if surface drainage from the factory is possible, the water may be contaminated to such an extent as to introduce undesirable bacteria in such numbers that the normal course of fermentation may be changed. The quality of the water, aside from flavor, can best be determined by making a curd test (p. 99) which is done by adding some of the water to boiled milk, and incubating the same. If "gassy" fermentations occur, it signifies an abnormal condition. In deep wells, pumped as thoroughly as is generally the case with factory wells, the germ content should be very low, ranging from a few score to a few hundred bacteria per cubic centimeter at most. The danger from ice is much less, for the reason that good dairy practice does not sanction using ice directly in contact with milk or cream. Then, too, water is largely purified in the process of freezing, although if secured from a polluted source, reliance should not be placed in this method of purification, for even freezing does not destroy all vegetating bacteria.

The ordinary house fly is an important source of contamination in creameries, cheese factories and city milk plants. They are of importance not only in increasing the number of fermentative bacteria in milk but they may serve to contaminate it with disease-producing organisms. The windows of all places where milk is handled, whether on the farm or elsewhere should be screened.

It should be kept in mind in the handling of milk and other dairy products that human food is being prepared and that cleanliness is desirable from every point of view, and that the methods of handling and production should compare with those used in the preparation of foods which like milk cannot be cleaned when once polluted. Desirability, keeping quality, healthfulness and the value of every product made from milk depends upon the extent and amount of contamination.

CHAPTER IV.

INFECTION OF MILK WITH PATHOGENIC BACTERIA.

That the disease-producing, or pathogenic bacteria, are able to infect milk supplies is shown by the fact that numerous epidemics of contagious disease have been directly traced to milk infection. Milk is generally consumed in a raw state, and as a considerable number of this class of organisms are able not only to live but actually grow in milk, which is such an ideal culture medium for the development of most bacteria, it is not surprising that disease processes should be traced to this source. The organisms in milk capable of causing disease do not alter or change its physical properties sufficiently to enable their presence to be detected by a physical examination.

Origin of pathogenic bacteria in milk. Disease-producing bacteria may be grouped, with reference to their relation toward milk, into two classes, depending upon the manner in which infection occurs:

Class I. Disease-producing bacteria capable of being transmitted directly from a diseased animal to man through the medium of infected milk.

Class II. Bacteria pathogenic for man but not for cattle, which are capable of thriving in milk after it is drawn from the animal.

In the first group, the disease produced by the specific organism must be common to both cattle and man. The organism must live a parasitic life in the animal, developing in the udder, and so infect the udder. It may, of course, happen that diseases toward which domestic animals alone are susceptible may be spread from one animal to another in this way without affecting human beings.

In the second group the bacterial species live a saprophytic existence, growing in milk, as in any other nutrient medium, if it happens to find its way therein. In such cases, milk indirectly serves as an agent in the dissemination of disease, by giving conditions favorable to the growth of the disease germ.

By far the most important of diseases that may be transmitted directly from animal to man through a milk supply is tuberculosis, but in addition to this, foot and mouth disease (aphthous fever in children), anthrax, and acute enteric troubles have also been traced to a similar source of infection.

The most important specific diseases that are disseminated through subsequent infection of the milk are typhoid fever, diphtheria, scarlet fever, and cholera, but, of course, the possibility exists that any disease germ capable of living and thriving in milk may be spread in this way. In addition to these diseases that are caused by the introduction of specific organisms (the causal organism of scarlet fever has not yet been definitely determined), there are a large number of more or less illy defined troubles of an intestinal character that occur especially in infants and young children that are undoubtedly attributable to the activity of micro-organisms that gain access to milk during and subsequent to the milking, and which produce changes in milk before or after its ingestion that result in the formation of toxic products.

Tuberculosis. This disease is by far the most important bacterial malady that affects man and beast. In man, it assumes a wide variety of phases, ranging from consumption in the lungs, which is by far the most common type, to scrofulous glands in the neck, cold abscesses, hip-joint, and bone diseases, as well as affections of the bowels. These various manifestations are all produced by the inroads of the specific organism, *Bacillus tuberculosis.* The bovine, as well as swine, fowls, and other warm-blooded animals, are also affected with similar diseases. In man, the importance of the malady is recognized when it appears that fully one-seventh of the human race die of this scourge. In cattle, the disease is equally wide-spread, particularly in those countries where live stock has been intensively developed. In the northern countries of Europe, such as Denmark, Germany, England, France, and the Netherlands, as well as in Canada, and this country, this disease has been most widely disseminated. This has been occasioned, in large measure, because of the exceedingly insidious nature of the disease in cattle, thereby permitting interchange of such stock without the disease being recognized. Tuberculosis is found more abundantly in this country in dairy than in beef stock. Dairy cattle are, however, not more susceptible, but the closer environment in which milch cattle are kept, and the fact that there has been greater activity in the matter of introducing improved strains, accounts for the larger percentage of affected animals.

It has been a disputed question for some years whether the organisms producing bovine and human tuberculosis are identical, or from the practical standpoint, whether the bovine type of disease is transmitted under natural conditions to man. The bacteriologist can readily detect differences in appearance, in growth of cultures, and in disease-producing properties between the two strains. Of the two, the bovine is much the more virulent when inoculated into experimental animals. In a considerable number of cases, record of accidental infection from cattle to man has been observed. These have occurred in persons making post-mortem examinations on tuberculous animals, and the tubercular nature of the wound proven by excision and inoculation.

More recently, since the agitation by Robert Koch of Germany, a number of scientific commissions have studied particularly the problem of transmission, and the best evidence now at hand indicates that the danger to the human from the bovine is confined practically to children. A very considerable percentage of glandular tuberculosis in children apparently shows the bovine type of organism.

Manner of infection in man. In the main, the source of the malady may be traced either to air infection or to the food, if one disregards the comparatively small number of cases of wound infection. Air, most frequently, is the medium of transfer, because of the carelessness of the infected person in disposition of sputa, which is exceedingly rich in tubercle organisms. But it has been conclusively shown in later years that while the germ itself is disseminated through the air, the disease is not contracted directly by inhalation. Where the organisms are inhaled into the nasal passages, they may be swallowed and pass through the wall of the intestine, finding their way to the lung, and there develop, without leaving any trace of their passage. Such is probably the course of events in the case of consumption.

Food may also possibly serve as a medium of infection.

The contamination of solid food from flies and other sources is, of course, a possibility, but tuberculous meat from cattle and swine is much more likely to occur, although it must be said that the processes of preparing such food for use (roasting, frying, and boiling) are sufficient to destroy the vitality of the causal organism. The fact that most food products of this character are now inspected renders this possibility less likely to occur.

Unquestionably, the likelihood of ingesting tubercle organisms is much greater with milk than with any other food supply, as milk is consumed usually in an uncooked state, and as microscopic and physiologic tests indicate that not infrequently milk from tuberculous animals shows evident presence of these organisms.

Distribution of the disease in animals. As practically any organ of the body may be affected with tuberculosis, it naturally follows that the lesions of this disease are widely distributed. The disease germ is introduced, in the main, through the lymph and not the blood system; consequently, in the initial stages the evidence of tuberculosis is often comparatively slight, and the lesion is restricted in its development. Where such a condition obtains, it is known as "closed," in contradistinction to "open" tuberculosis, where the diseased tissue is more or less broken down and is discharging into the circulation, or elsewhere. Manifestly, the danger of spreading not only in the affected animal itself, but to the outside, is much greater in the case of the open lesion. Especially is this true where the disease is present in the lungs or organs that have an exterior opening so that the material containing the organisms is discharged from the body in the sputum, manure, urine or milk. The intestines themselves are rarely affected, but the lymph glands associated with the intestinal tract are not infrequently involved.

Infection of milk with tubercle bacilli. In a small percentage of cases, the udder itself becomes involved. Where this condition obtains, one or more hard lumps are formed, which slowly increase in size, usually being restricted to one quarter of the udder. Sometimes the affected quarter may develop to an enormous size, producing a hard, painless tumor. Not often does the affected tissue break down into pus; consequently, no abnormal appearance is to be noted in the milk secretion until the disease has made very extended progress, in which case the percentage of fat generally diminishes.

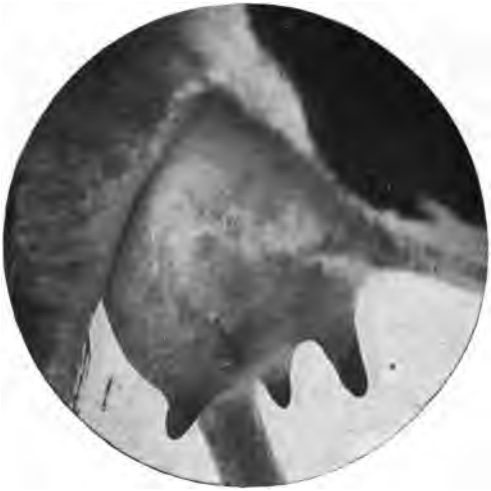

FIG. 16.—A TUBERCULOUS UDDER.

Note the much enlarged quarter. The milk from such an animal is certain to contain tubercle bacilli.

Whenever the udder shows physical manifestation of this disease, the milk almost invariably is rich in tubercle bacilli.

Tubercle organisms may also appear in milk of animals in which no physical symptoms of the disease are to be found. This fact has been demonstrated by microscopic and animal experiments, and it is also abundantly confirmed by the frequent contraction of the disease by calves and hogs when fed on factory by-products. This latter class of animals is particulaly dangerous, because there is no way in which the danger can be recognized.

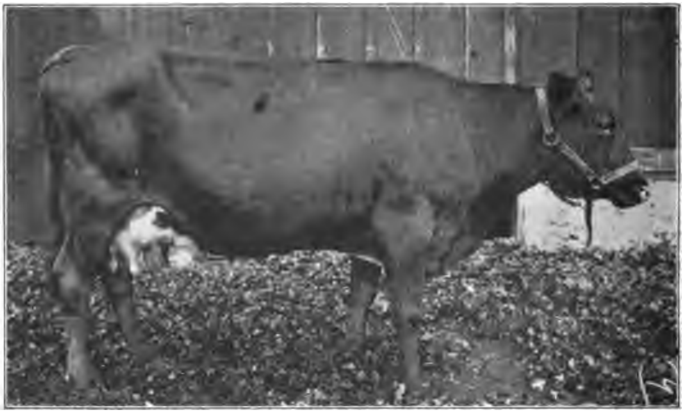

FIG. 17.—A TUBERCULOUS ANIMAL.

The animal appears perfectly healthy although she has had the disease for five years.

It has also been proven that milk may become infected through the feces. In coughing up material from the lungs and associated glands, the matter is swallowed, instead of expectorated, as in man. The organisms retain their vitality in the intestine, and are voided in the feces. Under ordinary conditions, the flanks and udder become more or less polluted with such filth, and the evidence is conclusive that infection of milk is not infrequently occasioned in this way. The fact that hogs following tuberculous steers in the feeding lots are very prone to acquire the disease is explained through the content of the manure of such animals in tubercle organisms.

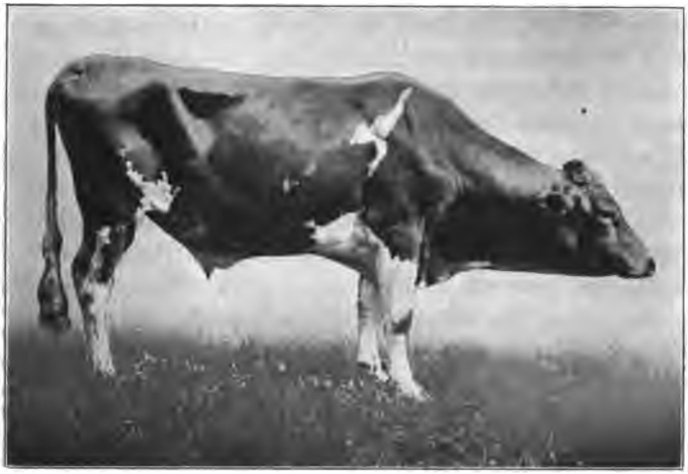

FIG. 18.—A TUBERCULOUS ANIMAL.

The last stages of generalized tuberculosis. Note the emaciated condition.

It must be kept in mind that many animals may be infected with tubercle bacilli and therefore have tuberculosis in the incipient stages, without their being able to disseminate the disease to others. In the early stages, they are bacillus-carriers without being necessarily dangerous at that particular time, but the possibility always exists, as the disease develops in the system, that the trouble may assume a more formidable character, and that slowly developing chronic lesions may become acute, and "open," in which case, the affected animal becomes a positive menace to the herd. As the time when the lesions change from the "closed" to the "open" type and the animal becomes a source of danger cannot be determined, the only safe way to do is to exclude the milk of all tuberculous animals from the general supply, whether for direct consumption, or for manufacture into dairy products and to look upon every diseased animal as a menace to the herd. This is rendered all the more necessary when the milk is used for the feeding of children, who are relatively more susceptible to intestinal infection than the adult. The early stages of the disease in cattle are, however, so insidious that no reliance can be placed upon the detection of the malady by physical means. Fortunately, in the tuberculin test, a method is at hand, which in a simple, but effective manner, enables the disease to be distinguished in even the earliest stages, long before recognition is possible in any other way.

Tubercle bacilli in dairy products. When infected milk is used for the preparation of butter and cheese, the organisms inevitably are incorporated in them. In the separation of milk a relatively large part of the tubercle organisms in the milk appear in the cream. In the making of cheese even more of the organisms are held in the curd. In butter and cheese, as in milk, no growth of the organism can take place; however, the vitality of the organism is retained for a considerable number of months. It is not believed that these products are of much importance in the spread of tuberculosis in the human family, since they are not consumed by children to any extent. Cream is to be considered as a means of distribution since it is often used by children.

Treatment of tuberculous milk. It is easily possible to treat milk or factory by-products so as to render them positively safe. The process of pasteurization or sterilization is applicable to whole milk, and when effectively done destroys entirely the vitality of any tubercle bacilli. In making such exposure, care should be taken to prevent the formation of the "scalded layer," as the resistance of the organism toward heat is greatly increased under these conditions. In a closed receptacle, 140° F. for 15 to 20 minutes has been found thoroughly effective in destroying this organism. A momentary exposure at 176° F. is likewise sufficient. This is the method that is almost universally used in Denmark in the manufacture of the finest butter.

In the treatment of factory by-products, heat should also be employed. In Denmark, compulsory pasteurization at not less than 176° F. is required. This treatment prevents not only the dissemination of tuberculosis among hogs and young cattle, but is equally efficacious in preventing the spread of foot and mouth disease.

The per cent of tuberculous milch cows varies widely in different sections of the country, being greatest in the older dairy sections, and in those supplying milk to the cities, on account of the constant buying and selling of animals, thus giving more frequent opportunity of introducing the disease into the herds. Throughout the country at large, probably less than ten per cent of the cows are tuberculous, and it is estimated that at least one per cent of the diseased animals have tuberculous udders. It has been suggested that the dilution of the milk of such animals with that of healthy cows would remove a great part of the danger from milk. In the case where the milk of a large number of herds is mixed, this may be of some importance, but in no case is it safe to assume that dilution of the milk of tuberculous cows is any guarantee of safety.

It has been shown that milk, perfectly normal in appearance, coming from a tuberculous udder could be diluted a million times and still produce the disease on inoculation into experimental animals. In the case of swine, the susceptibility is so great that a single feeding of infected milk, even in a very dilute condition, causes with certainty the production of the disease.

Some observers maintain that the contamination of the milk with the manure of tuberculous animals is of greater hygienic importance, than that coming from diseased udders, since the number of animals having tuberculosis of the lungs and intestines is far greater than those with diseased udders.

Economic aspects of bovine tuberculosis. Not only is this disease invested with much importance because of its inter-relation with the human, but from an economic point of view alone, it is undoubtedly the greatest scourge that affects the dairyman. Its insidiousness makes it exceedingly difficult to recognize. The consequence is that many fine herds become seriously involved before its presence is recognized. In the main, the disease is introduced into a herd by purchase, often by buying in pure-bred stock to improve the quality of the herd. Where the disease has been established in a region for some time, there is also danger that unheated factory by-products, as skim milk and whey, may function in its spread. Where such conditions prevail, the spread of the disease in the creamery district is exceedingly rapid. When once introduced into a herd, the disease sooner or later spreads from the originally affected animal to others in the herd. Close contact, and close confinement in ill ventilated stables facilitate the spread of the disease, and sooner or later, other animals acquire the trouble. This may all occur while all animals appear in a healthy condition.

The symptoms of the disease in the earlier stages are quite indefinite. As the disease progresses, the nutritive functions appear to be disturbed, and sooner or later, the body weight begins to decline, and finally intense emaciation ensues. Accompanying this condition, especially when the disease is in the lungs, is a cough, which is generally aggravated with active exercise. While the run-down condition permits frequently of the detection of the disease in the advanced stages, it is wholly impossible with any accuracy to diagnose the trouble in the incipient stages. It is at this stage that the tuberculin test comes to the aid of the stockman.

Tuberculin test. This test is made by hypodermically injecting into the body of the animal a small quantity (about 2 c. c.) of tuberculin, and noting the temperature of the animal, before and after the injection. Tuberculin, a product of the growth of the tubercle bacillus, when injected into the body causes a marked rise in temperature, in the case of an animal affected with the disease, and no such elevation in the case of a healthy animal. The process of preparing tuberculin makes it absolutely free from danger, so far as liability of producing the disease, or in any way injuring the animal, is concerned. Fig. 19 shows the temperature range of both reacting and non-reacting animals. While the test is not absolutely infallible, it is so far superior to any other and all other methods of diagnosis that it should take precedence over them.

Miscellaneous diseases. There are a number of diseases that affect both human beings and cattle, the causal organisms of which may be transmitted through the milk. Foot and mouth disease is one wide spread in European countries but which has not yet gained a permanent foothold in this country. The ingestion of the milk, which always contains the causal organism, produces the disease in both humans and cattle. In the human the disease is very similar to that in cattle; it may end in death. Vesicles are produced in the mouth, on the lips, nose and fingers. The causal organism, which has not yet been demonstrated, may occur in butter or cheese. It is easily destroyed by pasteurizing the milk.

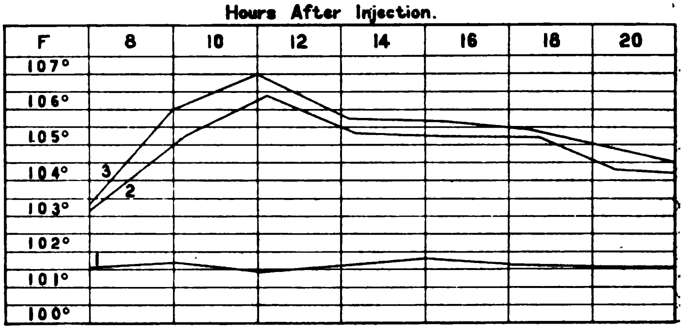

FIG. 19.—TEMPERATURE CURVES.

1, the temperature curve of a healthy animal after injection with tuberculin; 2 and 3, the temperature curves of tuberculous animals after injection with tuberculin. (After Moore.)

Anthrax, actinomycosis (lumpy jaw), rabies, and malta fever are diseases the organisms of which have been found in the milk of affected animals. In case of the first three, while the possibility exists of the infection of human beings by milk, it is improbable that such infection does normally occur. Malta fever is becoming an important disease in portions of southern Europe. It is produced by the use of milk of goats suffering from the disease.

Inflammation of the udder (garget), is a frequent trouble in every herd. It is marked by the swelling of one or more quarters, by the appearance of fever and changes in the appearance and composition of the milk. The inflammation may be caused by cold or injury, or by the invasion of the udder with pus-forming bacteria. In the first case the trouble is not likely to persist for any length of time, and does not spread to other members of the herd. The milk may be more or less stringy, and may show a slimy flocculent sediment. It cannot be asserted that such milk is harmful to man but it should be rejected on general sanitary grounds, and because it cannot always be differentiated from that coming from an udder in which the inflammation is produced by bacteria.

Inflammation caused by the invasion of the udder with specific bacteria is usually of greater severity, the entire gland often becoming involved. The secretion of milk may cease and the function of the diseased quarters may never be restored. The milk in the less severe cases may not be abnormal in appearance, but with increasing severity, the nature of the milk changes, until it may be a watery liquid. The milk of any animal suffering from any form of garget should be rejected, as it may cause trouble, especially in children.

The milk of animals suffering from indigestion, diarrhea, abscesses on any part of the body, as from those which have retained the afterbirth should be likewise rejected. In short only the milk of healthy animals should be used for human food; that from any animal suffering from any disease or which is receiving medical treatment should not be so used.

Typhoid fever. The most important disease germ, distributed through the medium of milk, that is unable to produce a diseased condition in the cow is the organism of typhoid fever. This malady is an intestinal affliction of man, and the germ causing the same is found abundantly in the dejecta, both solid and liquid, as well as in the blood circulation in certain stages of the disease. While the causal organism does not leave the body through the expired air, it is found abundantly in both the urine and feces. Therefore, the dejecta, and any articles that may be soiled with the same become a positive menace.

Many different methods of transmitting the contagion exist, such as water, food infected in various ways, contact with infected persons, and through the medium of milk. Milk is not so frequently the cause of dissemination as the other factors, but where milk supplies become contaminated, epidemics of considerable magnitude are wont to occur. The danger from milk is also aggravated by the fact that the typhoid bacillus is capable of withstanding considerable amounts of acid, and consequently finds, even in raw milk containing the normal lactic acid bacteria, conditions favorable for its growth. In a considerable percentage of cases, the disease is not sufficiently severe to cause the patient to take to his bed. These so-called "walking typhoid" cases are particularly dangerous, because they serve to spread the disease organism more widely.

Where outbreaks are caused by milk, they can readily be traced by means of the milk route, as there are always a sufficient number of susceptible persons, so that outbreaks of epidemic proportions develop. In the Stamford, Conn., outbreak in 1895, 386 cases developed on one milk route. In this case it was shown that the carrying cans were thoroughly washed, but were later rinsed out with *cold* water from a polluted shallow well.

The mode of infection of milk varies, but in general, the original pollution is occasioned by the use of infected water in washing the utensils, or a case of "walking typhoid" or bacillus carrier, as they are sometimes called, who directly infects the milk. In case of sickness in rural families, some member of the household may serve in the dual capacity of nurse and milkmaid, thus establishing the necessary connection. Busey and Kober report twenty-one outbreaks, in which dairy employees also acted in the capacity of nurses. The fact that the urine of a convalescent may retain the typhoid germ in large numbers for some weeks renders the danger from this source in reality greater than from feces, as, naturally, much less care is exercised in the disposition of the urine.

The house fly is now regarded as one of the important means of spreading typhoid fever, indeed it is often called the "typhoid fly." The infectious material deposited in an open vault may serve as a source from which the fly carries the organisms to milk and other foods in the house or elsewhere. The protection of vaults and the screening of every place where human food is handled or prepared is the only protection.

It should be emphasized that in the case of the tubercle organism, no growth ever occurs in milk, but with the typhoid bacillus, growth is possible. It thus needs but the contamination of the milk with the smallest particle of material containing them to seed the milk. By the time it is consumed it may contain myriads of the disease-producing organisms.

Diphtheria. This is a highly infectious disease, affecting in the main children, and is characterized by the formation of membranous exudates in the throat and air passages, which are teeming with the causal organism, the diphtheria bacillus. This organism is capable of forming highly toxic products, and it is to the effect of these poisons that its fatal result is generally due. The organism is thrown out from the body, in the main, through the mouth, the surroundings of the patient being infected directly from the air, and indirectly, by contact with polluted hands, lips, etc. Thus, the germ deposited from the lips of a case of the disease, on the common drinking cup, slate, lead pencils, toys, and the like, may easily pass from child to child. Not infrequently, the causal organism persists in the throat long after all evidence of membranous growth has subsided, and so the child itself may act as a "bacillus carrier."

Not so many epidemics of diphtheria as of typhoid have been traced to milk, but the evidence is sufficient to indict milk as a disseminator of contagion. In several cases, the diphtheria germ has actually been isolated from infected milk supplies. Actual growth of the diphtheria germ is said to take place in raw milk more rapidly than in sterilized.

Scarlet fever. While the germ of scarlet fever has not yet been isolated. and therefore its life history in relation to milk cannot be depicted so accurately, yet milk-borne epidemics of this disease are sufficiently abundant to leave no doubt but that this food medium may sometimes serve as a means of disseminating such troubles. Infection of the milk doubtless comes in the case of this disease from direct contact with a person suffering from the malady.

Cholera. While this disease is of no practical importance in America, owing to its relative infrequency, yet outbreaks of cholera have been traced to a milk origin, in spite of the fact that the causal organism is more sensitive to the action of acids than most disease-producing bacteria. In several outbreaks in India, milk has been the medium through which the disease was spread. Generally, infection of the milk has been traced to the use of polluted water.

Children's diseases. An exceedingly high mortality exists among infants and young children in the more congested centers, especially during the summer months. In the main, the cause of these troubles is due to intestinal disturbances, and unquestionably, the character of the food enters largely into the problem. As milk constitutes such a large proportion of the diet of the young, and is so susceptible to bacterial invasion, it would appear probable that much of the trouble of this character is due to the condition of this food supply. This is rendered more probable when it is remembered that bottle-fed infants suffer a much higher mortality than breast-fed children, due probably to the fact that the lengthened period between the time the milk is drawn and consumed permits of abundant bacterial growth. Much carelessness also prevails among the poor in cities, relative to the care of utensils used in feeding children. Nursing bottles often serve to infect the milk. Where milk is pasteurized, or properly heated, it has been found that the mortality rate has been greatly reduced, thus indicating that the condition of the milk was directly responsible for the death rate. In fact, the mortality from these indefinite intestinal troubles probably exceeds that from all of the specific infectious diseases combined. Improved care in handling this sensitive food supply will do much to better conditions in this direction.

Ptomaine poisoning. Acute poisoning affecting adults as well as children, not infrequently occurs from the use of foods of various kinds. Cases of poisoning arising from the use of shell fish, canned meats, ice cream, cheese, and other dairy products, are from time to time reported. These troubles are due to the production of toxic compounds, in the main, probably caused by bacterial decompositions. Often such troubles may affect a number of persons, as at banquets and such gatherings, thereby giving the semblance of an epidemic. While such troubles are doubtless to be ascribed to bacterial activity, they are not transmissible from person to person.

In the case of troubles arising from ice cream and such confections, the probable cause is due to the storage of milk or cream under refrigerator conditions, where germ growth can go on in the product, and yet the temperature be sufficiently low to prevent the usual souring fermentations.

CHAPTER V.

FERMENTATIONS OF MILK.

Milk, under normal conditions, is always contaminated with bacteria coming from the most varied sources. If it is produced under clean conditions, the number of bacteria will be small, but in any case, the number of kinds of bacteria that find their way into milk will be large. Many of them find in milk at ordinary temperatures suitable conditions for growth; they use a portion of some of the constituents of the milk as food, producing certain other compounds that are known as "by-products." These by-products impart to milk a taste and odor that is not found in fresh milk. The effect of the action of bacteria may also be made evident by the change in the appearance of the milk. When these various changes become evident to the senses, either by taste, smell or sight, the milk usually is so modified as to be unfit for many ordinary purposes. The preservation of milk, a subject to be treated later, is a study of the ways of preventing or retarding the growth of bacteria in milk, and thus delaying the time when evidences of their action first become apparent.

Each class of bacteria produces more or less specific changes in the milk as a result of their growth. Certain bacteria are of the greatest benefit to the butter and cheese maker, while others are distinctly harmful to the manufacturer of dairy products. The changes produced by the different bacteria are called "fermentations" of milk, each being most commonly named from the most important by-product formed.

Acid fermentation of milk. Fresh milk has a sweet taste and little or no odor, but if it is allowed to stand at ordinary temperatures, it sours; the taste is no longer sweet because the sweetness of the sugar of the milk is masked by the acid produced from the decomposition of a portion of the sugar by the bacteria. The change in odor and taste of milk is apparent long before the appearance is altered and increases in intensity as the acid-fermentation progresses. The first alteration in appearance is most usually one of consistency; the liquid milk is transformed into a semi-solid mass. The terms "curdling" and "sour" are usually synonymous. Milk is, however, often said to be sour as soon as the acid fermentation has progressed to a point where it is evident to taste or smell. This process of souring, or the acid fermentation is so common a change that raw milk which does not show this type of fermentation is looked upon with suspicion, and, usually, justly so. The process in the past was thought to be something inherent in the milk, a natural and inevitable change. It is now known that this is not so, but that it is due to certain kinds of bacteria, and that if these are prevented from getting into milk, it will not sour, but will undergo some other less desirable type of decomposition.

The acid-forming bacteria comprise but a very small part of the total number of organisms that find their way into the milk during its production on the farm, yet in sour milk scarcely any other kinds of bacteria can be found. At ordinary air temperatures, the acid-forming bacteria grow more rapidly in milk than do any other forms, and the acid produced by them renders the milk an unfavorable medium for the growth of other bacteria. This is the reason why milk practically always undergoes the acid fermentation, although it is contaminated with a host of other kinds of bacteria. If a mixture of seeds is sown on low wet ground, certain kinds will grow best; if the same mixture is sown on drier land, other types will find most favorable conditions for growth, and the plants which appeared on the low land will not appear. The same condition is found in milk where the environment is most favorable for the acid-forming bacteria.

Amount of acid formed in milk. In this country the acidity of milk is expressed as so many per cent of lactic acid. A milk that shows an acidity of one per cent should, theoretically, contain one pound of lactic acid in each one hundred pounds of milk. The acid determined does not actually represent lactic acid, as there are other substances in milk which act as acids, with the reagents used in the present methods of determining the acidity of milk. For instance, perfectly fresh milk has an apparent acidity of 0.13 to 0.18 per cent, although no fermentation has been produced. Other acids than lactic are formed in the acid fermentation, but the entire acid content is referred to as lactic when speaking of the acidity of milk. When the developing acidity of milk reaches 0.25 to 0.3 per cent, a sour taste becomes evident and the milk will curdle on heating. When the acidity increases to 0.6 to 0.7 per cent, the milk curdles at ordinary temperatures. The acidity continues, however, to increase until it reaches about 1 per cent, which is the maximum amount that will be produced in milk by the ordinary acid-forming bacteria. Milk contains about 4 per cent of milk sugar, all of which is fermentable. If this were all decomposed by bacteria, the acidity of the milk would actually exceed 4 per cent. It is thus evident that the reason why more acid is not formed in milk is not because of any lack of sugar. The bacteria, like all other kinds of living things, are injured by their own by-products, unless these are constantly removed in some way; in milk the bacteria cannot escape the action of the acid which they themselves have formed, consequently growth ceases. The amount of acid formed is dependent on the kind of bacteria present and on the composition of the milk. Certain bacteria will not produce enough acid to cause the curdling of the milk; still others will form 2 or even 3 per cent. These types, however, do not play any important part in the spontaneous souring of milk.

In milk the acid first formed combines with the ash and casein to form salts which do not seriously affect the growth of the bacteria. Ultimately, the limit of the ash and casein to take up acid is reached, and free lactic acid which is harmful to bacterial growth appears. If the content of casein and ash constituents is high, a higher degree of acidity will be reached than in a milk with a lower content. If a large part of the volume of the milk is made up of a compound that has no role whatever in the acid fermentation, such as the butter fat in cream, the amount of acid formed per unit volume of milk will be reduced, since in determining the acidity, a definite volume of milk is taken, and the acidity is expressed, as such a per cent of this amount.

Types of acid-forming bacteria. When substances undergo decomposition, it is a common belief that compounds offensive to the odor and taste are formed; but such is not necessarily the case. The products of the decomposition may be as agreeable and as harmless as the compounds decomposed. Whether the decomposition products of any substance are offensive or not is dependent on the kinds of micro-organisms acting on it. There are forms of acid-producing bacteria that change milk in odor, taste, and appearance, yet the sour milk is not offensive in any sense of the word. Other bacteria also sour the milk, but produce offensive odors and a disagreeable taste. Thus, the acid-forming bacteria may be divided into two main groups, which may be designated as desirable and undesirable. This division is of importance to the butter and cheese maker and to the consumer of milk.

Desirable acid-forming bacteria. If milk is produced under clean conditions, it is not likely to have a disagreeable odor or taste at any time, even when it is sour; rather the taste is agreeable like that of good butter milk. The curd is perfectly homogeneous, showing no holes or rents, due to the development of gas, and there is but little tendency for the whey to be expressed from the curd. This type of fermentation is produced by the group of bacteria to which has been given the name, *Bacillus lactis acidi.*

The main by-product of this group of bacteria is lactic acid; small amounts of acetic acid and alcohol, with traces of other compounds, are also formed. The agreeable odor and to some extent the flavor of milk fermented by these bacteria is due to other by-products than lactic acid, for this has no odor and only a sour taste. The acid fermentation of milk is often called the lactic acid fermentation. In reality only the fermentation produced by the desirable group in which lactic acid is the most evident by-product should be thus called.

The bacteria of this group may enter the milk from the dust coming from the coat of the cow. They are also found in the barn dust and on cultivated plants. Under ordinary farm conditions, the larger part of those found in milk come directly from the utensils. If the milk is drawn under extremely clean conditions and care is taken to sterilize the utensils, but few acid-forming bacteria of any kind will enter the milk; under such conditions most of the acid-forming bacteria will belong to the group in

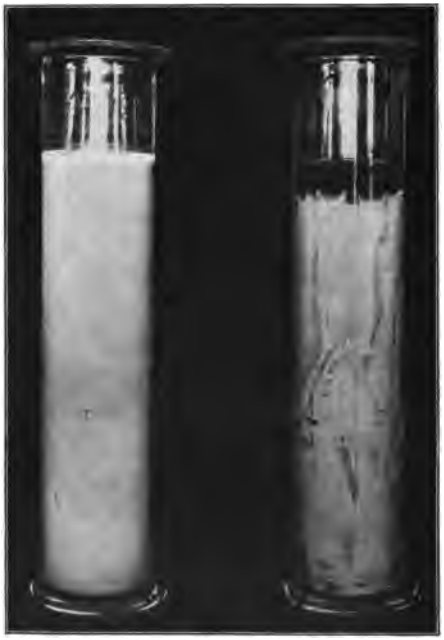

FIG. 20.—DIFFERENT TYPES OF CURDS.

On the right a solid, homogeneous curd produced by desirable bacteria; on the left, the curd produced by harmful bacteria. Note the gas holes and free whey.

question. They find, however, such favorable conditions for growth in milk that they develop more rapidly than most other types with which milk becomes seeded; consequently under normal conditions, they gain the ascendency and so control the type of fermentation.

The desirable type of acid-forming bacteria do not form spores; hence, are easily killed by heating the milk. They can grow in the presence or in the absence of free oxygen. In the bottom of a can of milk or in the middle of a cheese, there is no air, yet these bacteria grow as well under these conditions, as in milk exposed to the air. The range of temperature for growth varies from 50° to 100° F. but development is most rapid at 90° to 95° F.

This group of bacteria is of the greatest service in every branch of the dairy industry, whether in butter or in cheese making, or in the sale of milk in the city. The dairy industry is dependent upon fermentative activity, as much as the manufacture of beer or wine, and the main basis of this is the acid fermentation of the milk by these desirable types of bacteria.

Although milk contains a large amount of nitrogenous substances (casein and albumen), it does not undergo putrid decomposition, as do meat and eggs, not because it is not fitted for the growth of the bacteria causing that type of change, but because the acid formed in it stops the growth of the putrefactive bacteria. If a sample of milk is placed in a stoppered bottle, it will have much the same taste and odor at the end of several months as at the end of a few days. The acid acts as a preservative, like the vinegar in pickles, or the acid in silage and in sauerkraut. Meat placed in a stoppered bottle which is then filled with milk will be preserved.

The products formed in the decomposition of meat and eggs are not only offensive but may also be injurious to the health of the consumer. Milk that has been fermented by the desirable kinds of acid-forming bacteria is not harmful. It is consumed in a variety of forms (buttermilk, cottage cheese) as a common article of food and its use is rapidly increasing. The preparation of the pure culture buttermilks or artificially soured milks that are now so frequently recommended for digestive troubles rests upon an acid fermentation of this type.

Undesirable acid-forming bacteria. Other types of bacteria capable of forming substances that impart to milk an offensive odor and a disagreeable taste not infrequently appear instead of the desirable group. Instead of producing from the sugar of milk large quantities of lactic acid, these types generate other acids, such as acetic and formic, which impart a sharp taste to the milk. Gas is also formed, hence, the curd is spongy instead of being solid. The presence of gas in milk is thus an evidence of an undesirable type of fermentation.

This class of bacteria enters the milk with the dust, dirt, and manure, in which materials they are especially abundant. No spores are formed; hence they are easily killed by heating the milk. They grow both in the pressence and in the absence of free oxygen. High temperatures favor their growth, most rapid development taking place at 100° to 103° F.

Spontaneous fermentation of milk. The normal souring of milk is due to a mixture of these two groups of bacteria. The relative proportions existing between the two in any sample of milk is dependent on a number of factors, most important of which is the degree of cleanliness exercised in the production of the milk. Where careless conditions obtain under which dust and manure particles find their way into milk, it becomes more abundantly seeded with gas-generating bacteria, and consequently, the type of fermentation is undesirable. If, however, the milk is drawn into clean utensils and care is taken to exclude dirt, the pure lactic acid types are able to control the character of the changes produced, and a clean, pleasant tasting liquid results. It will be seen that things are well arranged by nature; one of the most important food products undergoes a type of decomposition that is not offensive and when produced under clean conditions, the sour milk is as healthful a food as is the fresh product. Thus there is every reason for cleanliness in the production of milk, for cleanliness' sake and because clean milk means better products, and greater returns to everyone, producer and dealer.

There are other kinds of acid-forming bacteria in milk but they are of small importance compared with those just discussed. Some of the bacteria derived from the inside of the udder of the cow form acid, but these forms grow very slowly in milk at ordinary temperatures, and have no influence on the keeping quality.

There is also found in milk, more or less constantly, bacteria that produce large amounts of acid, 3 per cent and above. These grow very slowly, or not at all at ordinary temperatures, and are not supposed to be of any importance in milk, as far as keeping quality is concerned. Their presence may be shown by placing the milk in a tightly stoppered bottle and by keeping it in a warm place for a week or two; the increased acid will be evident to the taste. This form is not inhibited in its growth by the presence of small amounts of free acid as are the kinds previously discussed.

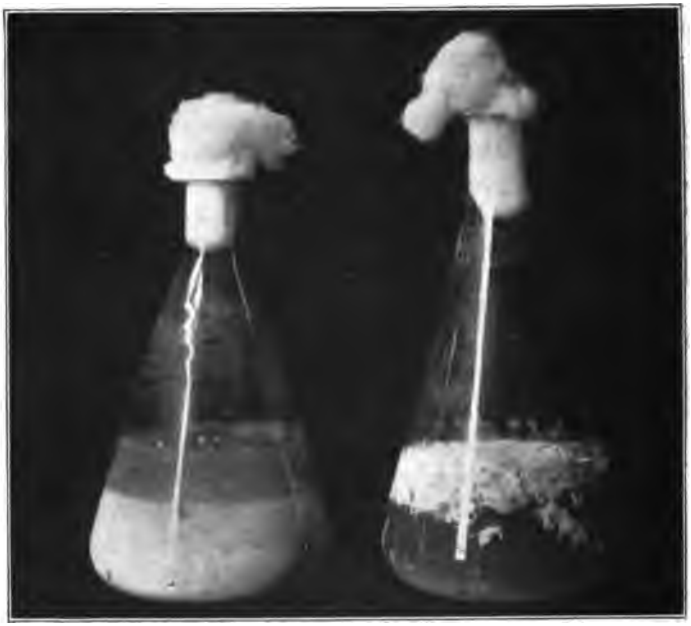

FIG. 21.—DIFFERENT TYPES OF CURDS.

The flask on the left shows the soft curd produced by the bacteria that curdle the milk without the production of acid. The flask on the right shows the gassy curd formed by butyric acid bacteria in pasteurized milk.

Sweet curdling fermentation of milk. Samples of milk are sometimes found that are curdled, but which do not taste sour, or have the normal odor of sour milk. The curd is usually soft and the taste bitter. It is evident that the curdling cannot be due to the same factors as in the normal souring of milk. Such a change is similar to the action of rennet which is used to curdle the milk in cheese making. This ferment will curdle perfectly sweet milk, producing a curd that looks like that formed in sour milk. The cause of these sweet curdling milks, which appear from time to time, is due to the introduction of certain bacteria which have the power of secreting an enzyme resembling that found in rennet. In such cases the milks curdle prematurely and without the development of much acid. The curd may gradually disappear, for the bacteria also produce another enzyme that digests the curd, and thus renders it soluble. When this advanced phase becomes evident, it is often called the digestive fermentation of milk. This change is produced largely by putrefactive bacteria of various kinds that find their way into milk with dust and dirt. Many of them are spore formers; hence, are not killed when milk is heated, as in pasteurization, while the acid-formers are destroyed. Pasteurized milk is thus likely to undergo the sweet-curdling fermentation, if it is kept for any length of time. Raw milk rarely undergoes this type of decomposition, since the rennet-forming bacteria under ordinary conditions are unable to develop in competition with the acid-forming bacteria.

Butyric acid fermentation of milk. A fermentation that is much less frequently noted than the two previously discussed is known as the butyric fermentation, since butyric acid is the principal by-product. The causal bacteria cannot compete with the ordinary acid-forming bacteria in raw milk; hence it is most frequently noted in pasteurized milk, since the organisms produce spores and are not killed by the heating. Pasteurized milk under the action of the butyric acid bacteria undergoes a gassy fermentation, developing a pronounced acidity and the disagreeable odor of butyric acid, which resembles that of rancid butter. The butyric acid bacteria are anaerobic, and thus can grow in butter and cheese away from the air.

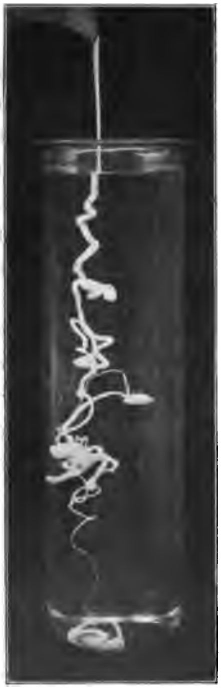

FIG. 22.—SLIMY MILK. It does not mix with water when poured into it.

Slimy or ropy fermentation of milk. A slimy or ropy condition of milk is frequently noted on the farm and in the dairy. Several causes for this abnormal condition exist. Sometimes the milk may be slimy when milked from the cow. This occurs most frequently in the case of inflammation of the udder which may or may not be due to bacteria. The direct cause of the abnormal condition in milk is the presence of fibrin and white corpuscles from the blood which form masses of slimy material; in such cases the trouble does not increase in intensity with age, nor can it be propagated by transference to another sample of fresh milk.

Another type of slimy milk is produced by the growth of certain types of bacteria which enter the milk after it is drawn from the udder. These may come from various sources. The bacteria concerned belong to two groups: (1) those that grow best in the air and do not form acid; (2) those that grow in the absence of air, throughout the entire mass of milk and which form acid. The slimy condition is noted in the milk only after the milk has been stored for some time; it usually increases with the age of the milk and can be produced in a second sample by transferring a little of the slimy milk to it.

The fermentation produced by the aerobic bacteria is most often met in bottled milk and cream during the warmer times of the year. On account of their relation to oxygen, the growth is confined to the surface of the milk and only the upper layer becomes slimy; thus when the cream is removed, the abnormal condition is noted. The sliminess is due to the mass of bacterial growth rather than to the production of any specific substance in the milk. This trouble may be of considerable economic importance to the dealer, as such abnormal milk is objectionable for ordinary use, but as far as is known, it is incapable of affecting the health of the consumer.

In numerous outbreaks of this trouble, the source of contamination has been traced to infection from well water or a stream, as the organisms causing the trouble are found naturally in water. Keeping the milk in a tank in the pump house sometimes permits of troubles of this sort, the water used for cooling giving opportunity for infection. Cattle wading in a stream sometimes pollute their udders and so indirectly infect the milk. Such outbreaks rarely persist for any considerable length of time, as the common acid organisms soon regain the ascendency.

Creameries and cheese factories are sometimes troubled with sliminess in starters. This seems to be due to some change which the ordinary lactic acid bacteria undergo on long propagation rather than to contamination of the starter. There are, however, types of acid-producing bacteria that are able to form specific substances in milk that are slimy in character. Two of these forms of slimy milk are of economic importance. The slimy whey (lange wei) of Holland is added to milk in the manufacture of Edam cheese, apparently serving the same purpose as the addition of the pure culture starter in cheddar cheese making. In Norway, a sour, slimy milk (taettemjolk) is used as food. It is produced by the addition of some previously fermented milk. This beverage is also used in some of the Norwegian settlements of Wisconsin, the original seed having been brought from Norway, and the bacteria maintained by constant propagation from one sample of milk to another. The milk has the odor and taste of butter milk, but is not especially appetizing in appearance to any one not accustomed to it; it is, however, as harmless to health as is any other form of sour milk. It is not known that any of these forms of slimy milk are distinctly harmful to the quality of butter or cheese.

Alcoholic fermentation of milk. The bacteria as a class are incapable of producing alcohol in appreciable amounts. The alcoholic beverages, beer, wine, and cider, are produced by the growth of yeast, in such sugar containing liquids as fruit juices, extracts of grains, etc. The common types of yeasts are incapable of acting on milk sugar, but they can ferment glucose, maltose, and cane sugar, forming equal amounts of alcohol and carbonic acid gas, which causes the effervescence of fermented and carbonated drinks. There are, however, some types of yeasts found in milk and its products that are able to ferment milk sugar.

All yeasts grow best in an acid medium, hence those fermenting milk sugar find suitable conditions for growth in sour milk or whey. They may at times become of economic importance in the cheese industry, because of the contamination of the milk with large numbers of them. The arrangement of the whey vat is often such that it cannot be completely emptied and cleaned; the sour whey thus presents favorable conditions for the growth of the lactose-fermenting yeasts. The return of the whey to the farm in the milk can that is often imperfectly cleaned may serve to contaminate the milk with the yeast. In the making of Swiss cheese the whey is often so handled as to favor especially the growth of such yeasts, and since this type of cheese is prepared from sweet milk, the competition between the yeast and the acid-forming bacteria is not so sharp as in the making of cheddar cheese. The writers have found several instances where considerable loss was occasioned in the Swiss cheese industry through the development of gassy cheese due to this type of fermentation.

Bitter fermentation of milk. Bitterness in milk may be due to bacteria that enter the milk after it is drawn from the cow, or it may be caused by the feed consumed by the animal. It has been previously shown that certain specific substances contained in the food may be absorbed and reappear in the milk. If the animal eats ragweed, lupines, or other plants containing bitter substances, the milk is likely to have a bitter taste, which will be noticeable at the time the milk is drawn. The milk of cows at certain advanced stages of lactation may show a bitter taste, due to a change in the ash constituents of the milk in which the lime salts are largely replaced by salts of sodium.

There are many bacteria that will impart to milk a bitter taste. Milk that has undergone the sweet-curdling fermentation is likely to be bitter, as is the case with pasteurized milk. Some of the acid-forming bacteria are able to develop a bitter principle, the milk retaining a pleasant odor and having the normal amount of acid, while the taste is intensely bitter. One of the authors (H) found in the case of a Wisconsin brick cheese factory, that the usual acid organism was almost wholly replaced by a bitter type.

Storage of milk at very low temperatures is conducive to the appearance of a bitter taste in milk, the explanation in this case being that the acid-forming bacteria are unable to grow at a low temperature, while some of the putrefactive forms can multiply and develop these astringent or bitter by-products.

Miscellaneous fermentations of milk. There are a number of other abnormal fermentations in milk that occur so rarely as to be of but little economic importance. Some, as the colored milks, are however, quite striking, and on this account have had much attention directed to them in the past. There are bacteria that are able to produce various colored substances, such as red, yellow, and blue. In case milk becomes seeded with large numbers of any of these kinds, it is very likely to be colored by the growth. Red milk may be due to bacteria, but more frequently is caused by the actual presence of blood in the milk, due to a wound in the udder, or the effect of a severe case of inflammation of this gland. Such a condition may be readily distinguished by allowing the milk to stand for a short time, in which case, if due to blood, the red corpuscles will soon settle to the bottom of the container, while bacterial troubles producing a red coloration are more evident on the surface.

It is also claimed that certain bacteria may impart a soapy taste or turnip flavor to milk.

Cycle of fermentations in milk. If a sample of milk is allowed to stand, it will undergo a certain sequence of fermentations that well illustrates the principle that one type of organisms is dependent on some other type to furnish suitable conditions for its development. This cycle of changes that normally occurs in milk is as follows: (1) The bacteria that come from the interior of the udder are the first to develop, but usually the change they produce is not evident.

(2) Of the types that gain admission, subsequent to the milking, the acid-producing species are able to adjust themselves most perfectly to the conditions that obtain in milk. Within a few hours they greatly predominate and soon the milk curdles under the production of acid. Their growth, however, is soon stopped by the accumulation of their own by-products.

(3) The semi-solid curdled milk, on account of its acid reaction then becomes a favorable medium for the growth of molds; a prevalent form, known as *Oidium lactis* usually develops as a white velvety layer. The molds in their growth form alkaline by-products, which tend to neutralize the acid reaction, so that in the course of two to three weeks, if the layer of the milk is not too deep (an inch or less), the chemical reaction of the milk becomes neutral or alkaline.

(4) The putrefactive bacteria which found their way into milk when it was first drawn, and which have remained dormant in the sour milk, now find favorable conditions for growth. As a result of their activity, the milk soon undergoes a putrid decomposition, which is marked by offensive odors.

If the milk is placed under such conditions as will exclude the growth of the mold, such as where the air is excluded from the surface, the sour milk will remain in that condition for an indefinite period, since the putrefactive bacteria are inhibited in their development by the acid, in a manner comparable to the preservation of pickles in vinegar, or the keeping of silage because of the acid that is produced as a result of the changes that the plant tissue undergoes when excluded from the air. The preservative effect of acids is of much importance in the case of certain dairy products (see Chapter VIII).

Determination of the cause of taints in milk. It is often of the greatest importance to be able to locate the cause of abnormal odors or tastes in milk, since methods for overcoming the trouble can be intelligently applied when the actual cause is known. An abnormal condition may be caused either by the direct absorption of odors before or after the milk is drawn from the animal, or it may be due to bacteria. If the milk appears bad-flavored when first drawn, and if such taint becomes less pronounced as the milk becomes older, it is likely that the trouble is due to some characteristic of the feed. Certain feeds, like green rye, rape, cabbage, and certain of the root crops, like turnips, impart a strong odor to milk, if the same are fed shortly before milking. If the tainted condition appears only some time after the milk is drawn, it may be due to the direct absorption of taints from the surroundings in which the milk is kept, or it may be caused by bacteria. These causes can often be differentiated, by noting whether the taint tends to increase in intensity with age. If such is the case, it is likely that the cause is of germ origin, but if the reverse is true, it cannot be ascribed with certainty to bacteria and recourse must be had to other methods, such as the transfer of a small quantity of the tainted milk to a sample of perfectly fresh milk, or preferably to some milk that has been heated to the boiling point and then cooled. In the case of an odor due to direct physical absorption, it will not appear in the inoculated sample, since the small amount transferred is not sufficient to be noted. If it is due to living organisms, the inoculation of the smallest quantity into a fresh sample is likely to reproduce the same change as originally noted.

Tests for the bacteriological condition of milk. Within certain limits milk can be indirectly examined as to its bacterial content without any especial equipment. Milk when drawn from the cow has an apparent acidity ranging from 0.16 to 0.18 per cent. By the use of any of the methods of determining acidity in milk, much can be told concerning the number of bacteria in the milk, and hence concerning its keeping quality. Milk that has an acidity of over 0.2 per cent is certain to contain many bacteria, and consequently will keep poorly. Such milk is of low value for market milk, but may not be objectionable for butter or cheese making. If the acidity is below 0.2 per cent, but little can be told as to the numbers of bacteria, since any increase in acid is always preceded by an enormous increase in the numbers of acid-forming bacteria.

A more important test than the acid test, from the standpoint of the butter and cheese maker, and even the milk dealer, is the fermentation test. In its simplest form, it consists in placing a sample of the milk to be tested in a warm place and noting the time required to curdle and the type of curd formed. In this country the fermentation test has been largely supplanted by the

Wisconsin curd test which possesses the advantage of detecting in particular the presence of bacteria harmful in cheese making.

The curd test is especially helpful in detecting the source of an abnormal condition in a milk supply coming from diverse sources. The milk furnished by each patron can be tested separately and the trouble located, perhaps in an individual herd; the offending herd determined, the test may then be used on the milk of individual cows. The cheese maker and the milk dealer should be able not only to detect which of the patrons

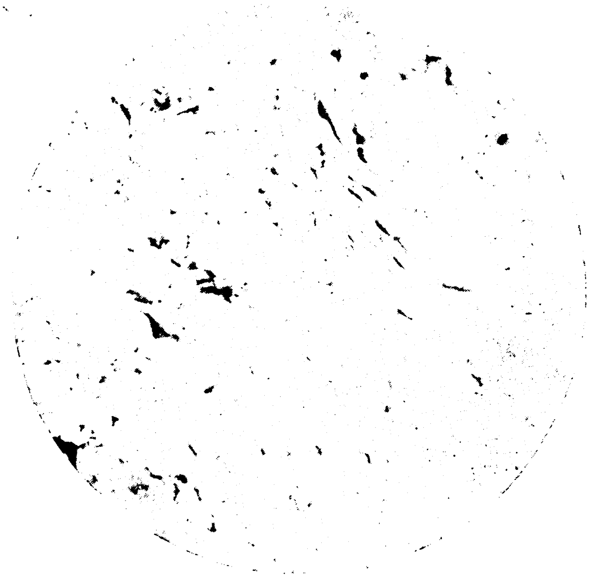

FIG. 23.—CURD TEST.

A good curd obtained from milk containing no harmful bacteria but many desirable organisms.

furnish him poor milk, but he should be able to give the patron definite instructions how to avoid the sources of such trouble. This information can be given only when the source is positively known.

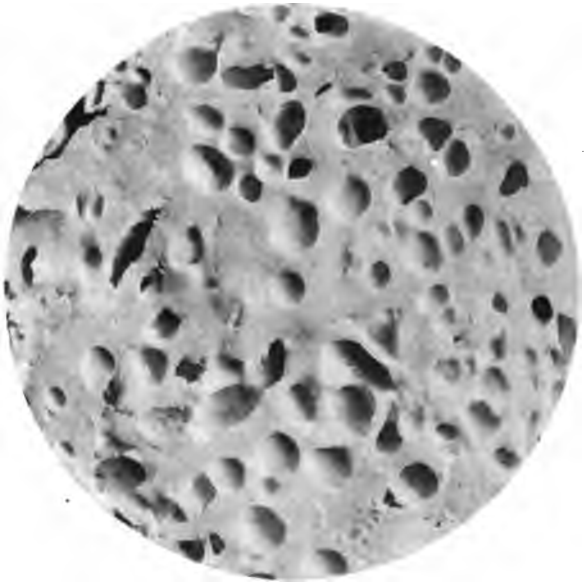

FIG. 24.—CURD TEST.

The curd obtained from milk containing many gas-forming bacteria. The irregular, angular holes are mechanical, due to the imperfect fusion of the pieces of curd.

The Wisconsin curd test is made as follows: Samples of the milk to be tested are placed in sterile pint fruit jars. The milk is warmed to 90° F., ten drops of rennet are added to each sample, and as soon as the curd is solid, it is cut into small pieces with a case knife so as to facilitate the expulsion of the whey. As the curd settles to the bottom of the vessel, the whey is poured off at intervals so that a pat of firm curd is left. As the milk curdles the bacteria are enmeshed and are carried with the curd. The jars are kept at a temperature of 100° to 105° F., since this temperature is favorable to growth of the bacteria that are sought, the gas-forming organisms. At the end of ten to twelve hours, the jars are examined; if the curd is solid, the texture firm, not mushy or slimy on the surface, if the odor is agreeable, it indicates that the milk contains few or none of the undesirable forms of bacteria. If the curd is full of gas holes, it is apparent that undesirable bacteria are present and under such circumstances the curd will not have an agreeable odor. If the gas-forming bacteria are numerous, the curd may even be spongy from the abundance of gas holes, and the undesirable odor more pronounced. Such curds are tough and rubbery. In some cases a bad flavor or odor is apparent even though the texture of the curd is not open and full of holes. The curd, the surface of which is slimy indicates undesirable organisms. A solid curd of agreeable odor is indicative of the presence of the desirable acid-forming bacteria. Such a milk is excellent from the standpoint of the butter or cheese maker, but may not be so desirable from the standpoint of the milk dealer on account of its poor keeping qualities. On the other hand a milk suitable from the standpoint of the milk dealer, on account of its low germ content, and hence good keeping quality, may give a poor curd test, since it will contain too few organisms to produce the normal acid curd. The milk will contain some bacteria no matter with what degree of cleanliness it has been produced. These will grow more rapidly at high temperatures and are very likely to injure the curd.

The test when used for market milk should be interpreted with this in mind.

If the results are to be of any value, the test must be made with care to avoid all sources of error; the tester must know that the bacteria causing the gas in the sample were originally present in the milk at the time the sample was taken, and that they have not come from the containers used or from other sources. To insure these conditions the jars must be thoroughly cleaned and then sterilized just before use, by placing them in cold water and bringing them to the boiling point, or sterilized by a thorough steaming. The sample of milk of a patron must be taken so as to avoid contamination from the milk of the other patrons. This can best be done by filling the jars as the milk is poured from the patron's can into the weigh can. In cutting the curds, the knife used must be dipped in hot water between each test to cleanse the same. In short, the test should be carried out with great care so that the tester is certain of the results obtained.

Other tests for the bacteriological condition of milk will be described in Chapter IX.

Overcoming abnormal fermentations. The lactic acid bacteria are often looked upon as normal to milk, and it is certain that they are to be classed as harmful, only as they injure the keeping qualities of milk. In milk designed for butter and cheese their presence is necessary. At times these desirable forms of bacteria may disappear, and be replaced by other less desirable types. In one case it was observed that the usual lactic bacteria had been replaced in a cheese factory supply by an acid-forming organism that produced an intensely bitter taste in the milk, thus rendering the cheese of no value. When such harmful forms appear, they must be overcome, and the normal types of bacteria replaced. A thorough cleaning of the milk utensils, attention to the cattle and all places from which such bacteria may find their way into the milk is often sufficient to cause a disappearance of the trouble. If the acid-forming bacteria have disappeared, the inoculation of the milk with cultures in ways later to be discussed is often of advantage. At times more stringent measures must be employed in order to destroy the harmful bacteria, such as the use of strong disinfectants.

Disinfection and disinfectants. If any building or room becomes infected with disease-producing bacteria, or if organisms causing abnormal fermentations become established in a factory, the use of a disinfectant that will destroy with great rapidity the life of bacteria is necessary. The disinfection of all types of dairy apparatus and utensils can be accomplished by thorough cleansing, and by the use of steam or boiling water. The disinfection of rooms and stables cannot be so readily accomplished.

Consideration must always be given to the resistance of the organism it is desired to destroy. Those that form spores are very resistant toward all chemical agents, while those that do not produce these resistant bodies are easily killed. In the dairy and factory, it is often necessary to destroy the organisms that develop in decomposing organic matter. Here, as in all disinfection, a thorough cleaning should precede the application of any disinfectant. Some chemicals act as deodorants, *i. e.*, destroy the offensive odor, without removing the cause. It is impossible effectually to destroy bacteria embedded in a mass of organic matter, and through the removal of the material itself, the larger part of the bacteria will be removed. The disinfectant then comes in direct contact with the surface to be disinfected, consequently destroys the bacteria not removed in the cleaning.

All places in which dairy work of any kind is done should be provided with an abundance of light and air. The direct rays of the sun have a powerful disinfecting action, and light makes evident accumulations of dirt that in a darker room would be unnoticed. Ventilation keeps the rooms dry and thus prevents the growth of mold and the development of a musty odor.

Disinfectants are divided into two classes: (1) solid materials used in suspension, or in watery solutions; (2) gaseous substances. The latter are preferable for room disinfection when their use is permissible, for the gas penetrates to every part of the space, even into the cracks. Gaseous disinfectants can only be used when the space is tightly closed, for the gas must be confined for several hours in the room, in order to make the process effective. Such disinfectants can often be used to advantage in the treatment of refrigerators and cheese rooms to destroy mold spores. In less tightly closed spaces, reliance must be placed on the use of the solid or liquid disinfectants.

Lime. Quick lime or stone lime has a considerable disinfecting action. On exposure to the air, quick lime becomes air slaked, and then has no disinfecting action whatever. Water-slaked lime used in the form of white wash, lime water, or the powder is effective. Air-slaked and water-slaked lime are similar in appearance, but a difference can be noted by placing a particle of each on the tongue; the air-slaked tastes like chalk while the water-slaked material causes the tongue to burn.

White wash is one of the most effective agents that can be used in the disinfection of barns, milkrooms, etc. Besides being a fairly strong disinfectant, it has a tendency to absorb odors, it encrusts the walls and lightens the interior of rooms. It can be applied with a brush or with a spray pump.

Carbolic acid and cresol compounds. These substances are among the cheapest and best disinfectants, but their use in the dairy is not advisable, on account of the penetrating and lasting odor. They can be used to advantage on the farm. Some of the proprietary compounds, as Zenoleum, Kresol, etc., are easily applied, since they mix readily with water in all proportions, forming a milky white emulsion that can be easily applied. They are less caustic and less poisonous than carbolic acid.

Corrosive sublimate. Corrosive sublimate is the most efficient disinfectant under ordinary conditions. It is such an intense poison that it must be used with caution in places to which stock have access, or in the dairy. A solution of one part of the salt to a thousand parts of water (half ounce to 4 gallons of water) is the standard generally used.

For gutters, drains, and waste pipes in factories, ferrous sulphate (green vitriol), and copper sulphate (blue vitriol), can be used to advantage. They are to be classed as deodorants rather than as true disinfectants. Since they have no odor of their own, they can be used in any amount in the dairy.

Sulphur can be used to advantage in the destruction of mold spores in cheese rooms, but the effect of the vapors of burning sulphur on germ life is relatively slight, unless there is an abundant supply of moisture in the air of the enclosed space, in which case sulphurous acid is formed which has a much greater effect. To have desired effect sulphur should be burned at the rate of three pounds to each one thousand cubic feet of space, and the room kept sealed for at least twelve hours. If sulphur is placed in an iron kettle which is set in a vessel of water, danger from fire will be avoided, and the heat generated by the burning sulphur will evaporate sufficient water to increase the effect of the fumes.

Formalin. Another disinfectant that may be used as a liquid or as a gas is formalin, which is a watery solution of the gas, formaldehyde. It is much more powerful in its action than sulphur, and has a great advantage over corrosive sublimate and other strong disinfectants in that it is not so poisonous to animals as it is to bacteria and fungi.

It can be used as a solution (one to five per cent) for the washing of woodwork, or for the treatment of any object, since it has no corrosive action. It can also be employed as a gaseous disinfectant for the treatment of rooms. It is most conveniently applied by suspending large cloths in the room and spraying them with the solution, then closing the room for a number of hours.

Bleaching powder. Chloride of lime, or bleaching powder as it is often called, is a good disinfectant, as well as a deodorant. It is used as a wash in the proportion of four to six ounces to a gallon of water. It must be used with care in factories since the free chlorine that is given off has a penetrating odor.

Fermented drinks from milk. Within the last few years a great deal of attention has been directed toward the preparation of various kinds of drinks from milk.

The use of such beverages has rapidly increased. Butter milk is one which meets with the greatest approval. The true butter milk from cream that has been soured by the desirable acid-forming bacteria has a mild agreeable acid taste, wholly free from any sharpness that is often noted in butter milk made from cream in which considerable numbers of the undesirable acid-forming bacteria have grown. Butter milk made from pasteurized cream soured with pure cultures will have good keeping qualities and is a most healthful drink for all classes of people, even for young children.

Butter milk is also prepared by allowing milk to sour and then breaking up the curd by stirring. If the type of fermentation is controlled as may be done (see Chapter VII), such a form of fermented milk is a most desirable drink. It is probably as healthful and has all the therapeutic properties that are ascribed to other forms of fermented milks such as the Bulgarian "Yoghurt."

This type of fermented milk is produced by an acid-forming organism that can form large amounts of acid, 2.0 or 3.0 per cent. The casein is dissolved to some extent and the remainder so changed, that it will remain in suspension for a long time in a finely divided form, after the curd has been broken up. Such milk is sold under various names at home and abroad. One of the authors (H) has found such organisms in practically all milks examined. If raw milk is kept warm (98° to 100° F.) in a stoppered bottle which is filled full, the acidity will be found to increase slowly from day to day, reaching a maximum in ten to fourteen days. If the milk is then examined, it will be found to contain large numbers of an acid-forming organism very different in appearance from the bacteria causing the rapid souring of milk at ordinary temperatures. This organism is very similar if not identical with the one found in the Bulgarian milk to which the name *B. Bulgaricus* has been given. The use of the milk fermented by this organism has spread rapidly because it is claimed by certain European bacteriologists that it has a favorable effect on the health of people, especially those suffering from intestinal troubles. It is not at all certain that ordinary sour milk or butter milk will not have the same effect; in fact in many of the fermented milks sold in Europe, *B. Bulgaricus* has not been found, but only the ordinary lactic acid bacteria.

Several alcoholic drinks made from milk, such as kefir and koumiss, have been originated among the nomadic tribes of Western Asia. Kefir is prepared from cow's milk by adding the kefir ferment in the form of grains which contain a number of kinds of bacteria and a yeast. The acid-forming bacteria impart a sour taste to the fermented milk, while the yeast forms carbon dioxide and about two per cent of alcohol. If the milk is allowed to ferment in stoppered bottles, the resulting product will be an acid effervescing drink, which is claimed to be more easily digested than sweet milk. This drink is used frequently in the treatment of invalids but it is improbable that it is more easily digested than ordinary soured milk or butter milk. The grains are removed from the fermented milk, and are then added to a quantity of fresh milk, or they may be dried and kept for future use. When needed again, they are soaked in water, then added to the milk.

Koumiss is made in Russia from mare's milk and has much the same composition as kefir. In America and

Europe it is made from cow's milk, by adding cane sugar and compressed yeast. The yeast ferments the cane sugar while the acid-forming bacteria ferment the milk sugar. There is thus obtained a drink that is similar in composition to the real koumiss, in which both the acid and the alcohol come from the fermentation of the milk sugar. In koumiss and kefir the curd is very finely divided and will remain in suspension for a long time as with butter milk.

CHAPTER VI.

PRESERVATION OF MILK.

It has been shown in a previous chapter that milk becomes contaminated with a multitude of bacteria not only on the farm where it is produced, but during the various stages, prior to its use. Many of the bacteria which find their way into milk are readily able to develop, and by their growth, render the milk unfit, or even harmful for human food. With the most stringent precautions that can reasonably be taken, it is impossible to avoid all contamination; hence, all grades of milk will soon spoil, unless some means of preservation is employed. Indeed, of all the foods classed as perishable, milk is the one that most rapidly deteriorates. Produced under ordinary conditions, it is unfit for ordinary use in a few hours if kept at 70° F.

There are three possible ways by which milk may be preserved: (1) The removal of bacteria that have gained entrance to it; (2) The prevention of growth of the contained bacteria; (3) The destruction of the contained organisms. In practice at least two and sometimes all of these methods are employed. The prevention of contamination, a subject discussed in Chapter III is in reality one of the most efficient means of preserving milk. In milk production, as elsewhere, prevention is preferable to cure. Milk produced under such conditions that its germ content is but a few thousand per cubic centimeter will keep much longer than that handled in the ordinary manner.

It might naturally be supposed that any method by which dirt is removed from milk would improve the keeping quality of milk, due to the reduction of bacteria, yet while the straining of the milk at the time of milking removes dirt of various kinds, it does not appreciably enhance the keeping quality, owing to the fact that the bacteria adherent to the dirt particles are washed off in straining, and pass through the pores of the strainer.

Filtration of milk. The fat globules of milk are much larger than the bacteria (Fig. 6); hence, a filter fine enough to remove the bacteria would likewise remove the fat from the milk. In some European cities milk is passed through sand filters, which are constructed by filling a suitable container with coarse sand at the bottom, and with finer sand at the top; the milk is forced upward through the layers of sand. Such a filtering process is a very efficient means of removing the dirt; but unless the filters are kept scrupulously clean, the bacteria are likely to grow in the filtering material, so that the number of organisms in the milk may actually be increased by the filtering process. It is necessay to remove the sand daily and thoroughly wash and sterilize the same. The extra care required in keeping these sand filters in sanitary condition has been the great objection to their employment in this country. Filters of other material such as cellulose have been employed but with no marked success.

Clarifying milk. A much more efficient and less troublesome means of removing the insoluble foreign particles from milk is to pass it through a cream separator, allowing the cream and skim milk to mix in the same container. The slime that collects on the wall of the separator bowl is made up of dirt, casein, bacteria, and the cellular debris from the interior of the udder. The bacteria are heavier than the milk serum, and would, therefore, be deposited on the wall of the bowl were it not for other factors that in a measure prevent this. The movement of the fat toward the center of the bowl carries into the cream a considerable proportion of the bacteria in the milk. The slime will always contain many more bacteria than the milk, but the per cent of bacteria thus removed is relatively low, due to the small amount of slime obtained from the milk, so that the actual effect of clarification on the keeping quality of milk is insignificant. The complete removal of all insoluble and therefore visible dirt is, however, regarded of sufficient value to warrant the use.

Machines have been devised especially for the clarification of milk. The speed with which the bowl revolves is much less than in the case of the ordinary cream separator. Milk that has passed through a clarifier creams much more rapidly and pefectly than does the milk which has passed through an ordinary separator.

From the standpoint of the consumer, all processes by which dirt is removed from milk are objectionable, since they make the milk appear cleaner and better than it really is, the harm having been done when the dirt and the adherent bacteria found its way into the milk. Much of this foreign matter dissolves in the milk and the adherent bacteria remain in the liquid; the separation of the undissolved dirt does not greatly reduce the number of bacteria present. The processes described change the appearance of the milk by the removal of foreign matter, but do not improve its quality in any way, as do those later mentioned.

Prevention of growth. The only legitimate way of preventing the growth of bacteria in milk is by holding it at temperatures at which the ordinary forms of bacteria cannot thrive. Bacterial growth is greatly checked at temperatures approximating 50° F., or below, although certain types multiply at the freezing point or slightly above. If food products are actually congealed, no germ growth occurs, and they may be kept quite indefinitely, but this process cannot be successfully applied to milk, as the fat and casein are physically changed, so that a normal emulsion can not again be made when the frozen milk is melted. The fat separates in visible masses as though the milk had been partially churned. On account of this fact milk must be stored at temperatures above the freezing point. In Denmark efforts have been made to preserve milk, that is to be shipped long distances, by freezing a portion of the milk, and placing a block of the frozen milk in each can after cooling the main mass of milk nearly to the freezing point. Even this method has not proven practical, and at present reliance is placed on thorough chilling of the milk. At 32° F., the lactic bacteria cannot grow, but other types, such as certain of the putrefactive forms grow slowly; the milk may, therefore, have no objectionable odor or taste and yet be swarming with bacteria. In cities the practice is followed of placing cream in cold-storage during the cooler periods of summer in preparation for an increased demand, during hot weather or on holidays. It seems probable that poisoning from ice cream may, at times, be due to the use of such cream.

Preservation by the use of antiseptics. Many chemical substances prevent the growth of bacteria when added to food supplies; such substances thus used are called *preservatives.* In the past some of these have been used in milk to a great extent, but at present, on account of stringent pure food laws, they are employed only to a slight extent. There is a great temptation for the small milk dealer in the city to employ them to preserve the excess of milk from day to day, as through the use of a few cents worth of some preparation, many dollars worth of milk may be kept from spoiling until it can be sold to the unsuspecting consumer.

Formalin has been most widely used in milk because it is a most efficient preservative; it is cheap and cannot be detected by the consumer, although it injures the digestibility of the casein. One ounce will keep one thousand pounds of milk sweet for twenty-four to forty-eight hours. Borax, boric acid, and salicylic acid have also been used, but these substances must be employed in much larger quantities than formalin. Bicarbonate of soda has sometimes been used although it is not a true preservative. Its effect is based upon the neutralization of the acid produced by bacterial growth. The treated milk does not taste sour so quickly, and the curdling of the milk is also delayed.

Many proprietary compounds for milk preservation have been placed on the market in the past, but the use of all of these is illegal in most states. The federal law also prohibits their use in all dairy products that pass into interstate commerce.

Within recent years a method for the preservation of milk was introduced by a Danish engineer, Budde, which consists of adding to milk a very small amount of peroxid of hydrogen which is a very efficient antiseptic. The peroxid is decomposed by some substance in the milk; the products of decomposition being water and free oxygen. The peroxid together with the application of heat at a comparatively low temperature (122° F.) is sufficient to destroy the larger part of the bacteria in the milk. Practical difficulties were encountered in the commercial application, so that it is probable the process will never be a commercial success.

For the preservation of composite samples of milk for analytical purposes, such as the Babcock test, strong disinfectants, as corrosive sublimate, are employed. This material is very poisonous, and renders the milk unchanged in appearance. Some coloring matter is therefore usually mixed with the sublimate in making the preservative tablets, so as to render their use more conspicuous. Corrosive sublimate not only stops all bacterial growth, but quickly destroys the life of the cells. Bichromate of potash is generally employed in the preservation of composite samples for the Hart casein test.

Destruction of bacteria in milk. Actual destruction of the life of bacterial cells by heat is one of the most important ways for preserving milk. Heat easily destroys the vegetating, growing bacteria, while the spores, of which there are always a number in milk, are very resistant. If, however, the growing organisms are destroyed, the milk will keep much longer than if it had not been so treated.

The process of pasteurization was first used by the French bacteriologist, Pasteur, for the treatment of the wines of his native district which were likely to undergo undesirable types of fermentations due to bacteria.

From the wine industry it was applied in the brewing industry, and was later found to be of the greatest service in the dairy industry. The process of pasteurization may be briefly defined, as the heating of milk to temperatures, varying from 140° F. and upward for a longer or shorter time, and subsequently cooling to a low temperature, so as to prevent the germination of the spores that are not destroyed by the heating.

Effect of heat on milk. When milk is heated it undergoes more or less profound changes, depending on the temperature and time of heating. Some of these changes are of practical importance, since they are more or less evident, and objectionable to the consumer.

In raw milk the fat globules are largely found in larger or smaller aggregates, rather than uniformly distributed throughout the serum. The surface of a mass of fat globules is smaller in proportion to the volume of the mass than is the case with single globules, hence globule clusters encounter less resistance in their passage through the serum, either as they rise to the surface in gravity creaming, or in the separator bowl. If these clusters are broken up, so that the globules are uniformly distributed, the milk will cream much less rapidly and completely. In the process known as "homogenization" of milk, the individual fat globules are broken into such small globules, that they cannot overcome the viscosity of the serum, and they remain distributed throughout the milk. In such cases, no cream rises, and even the cream separator is unable to remove the fat from such milk.

In selling bottled milk, it is highly desirable that the cream line should show distinctly. In normal milk, this line forms in a few hours, but where milk is heated to a high temperature, and agitated at the same time, the clusters of fat globules are broken apart and the creaming power injured. This physical change is dependent not only on the temperature, but also on the time of exposure. A momentary exposure at 160° F., or for 20 minutes at 145° F., is about the maximum limit which can be applied to milk without material injury to the creaming property.

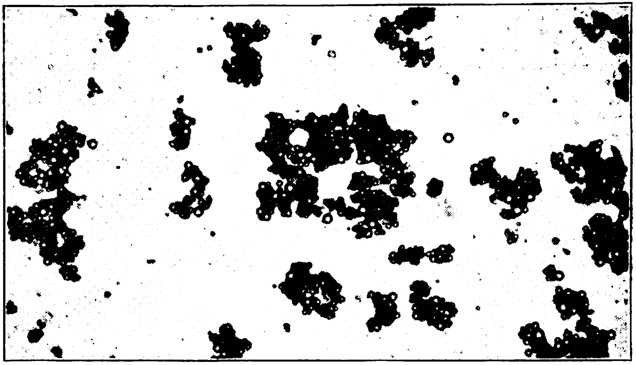

FIG. 25.—FAT GLOBULES IN RAW MILK.

In raw milk the fat globules are in masses of varying sizes. These rise to the surface quickly in gravity creaming.

The body or consistency of pasteurized cream may be restored by allowing the cream to stand for several days at low temperatures, or by the addition of a small amount of sucrate of lime. This substance, known to the dairy trade as "viscogen," is made by adding to a thick solution of cane sugar, some freshly slaked lime. The sugar solution permits of the dissolving of a much larger amount of the lime than is possible in water. When the liquid is allowed to settle, the clear solution is then decanted off and is used at the rate of about one part to 100 to 150 parts of cream. The fat globules are, by its action, brought into aggregates and the body of the cream thus restored. Viscogen contains nothing that is at all harmful, but milk and cream to which it is added must be sold under some distinctive name as "visco-cream," since the laws of practically all states do not allow the addition of any substance whatever to milk or cream.

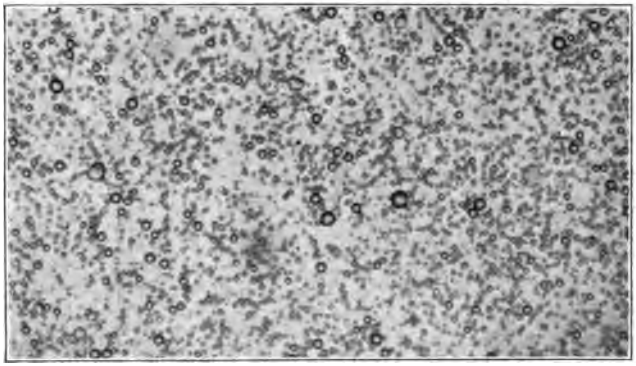

FIG. 26.—FAT GLOBULES IN HEATED MILK.

When milk is heated the masses of globules are broken up and the fat globules are uniformly distributed throughout the milk.

Heated milk has a taste unlike that of raw milk; to one not accustomed to it the taste is objectionable. This change is due to some extent to the expulsion of the carbon dioxid from the milk, the same as the insipid taste of boiled water. The production of this cooked flavor is dependent upon the time and temperature of exposure. It is claimed that heated milk is less digestible than raw, and a considerable amount of experimental work has been done, both on animals and children, in order to determine the relative digestibility of heated and raw milk. The results obtained have been contradictory. It is claimed that heated milk causes such diseases as rickets, scurvy and marasmus in children. It is probably

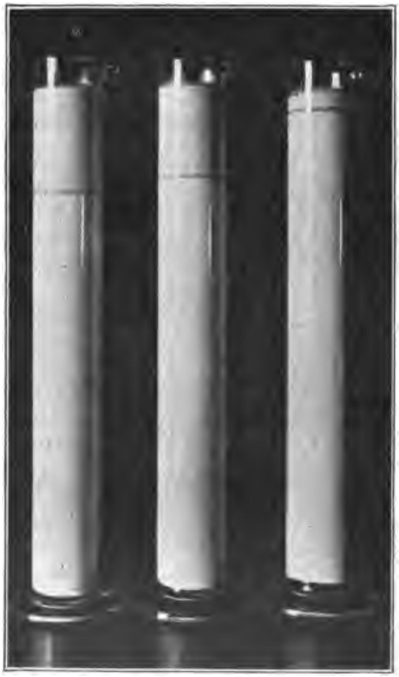

FIG. 27.—CREAMING OF MILK.

The cylinder on the left contains raw milk; that in the center, milk heated to 140° F. for twenty minutes; on the right, milk heated to 160° F. for twenty minutes. The dark line indicates the depth of the cream after twenty-four hours. The breaking-up of the fat globule clusters delays greatly the rising of the cream.

true that milk heated to the boiling point is less fitted as food for the young child than raw milk; but, on the other hand, it has not been proven that properly pasteurized milk is an unsuitable food for children. The best evidence has been accumulated in recent years, in many of the large cities of this country and of Europe, where pasteurized milk has been used with the greatest success in the feeding of children of all ages.

If pasteurization is efficiently done, the non-spore-bearing bacteria will be destroyed, and only the spores will remain. In this way the acid-forming bacteria are killed and the milk will not sour. If kept for sufficient time, it will, however, undergo putrefactive changes, such as have been described as ''sweet curdling'' of milk. The milk may appear normal to the taste and yet be in such a state of decomposition as to be undesirable or even harmful as food. Pasteurized milk may undergo an acid fermentation due to the development of the spores of the butyric acid bacteria; the milk on standing shows gas formation and the development of an objectionable odor.

The heated milk does not curdle readily when rennet is added due to the precipitation of the lime salts by heat. The curdling power can be restored by the addition of soluble lime salts or of acids.

Purpose of pasteurization. There are two reasons for the pasteurization of milk: (1) To improve the keeping quality; (2) To destroy any pathogenic bacteria it may contain. The first may be called the economic reason; the second, the hygienic reason for pasteurization. In the selection of a proper pasteurizing temperature, two factors must be taken into account: First, the effect of heat on milk, and second, the temperature necessary to destroy those forms of bacteria that are of the greatest importance, as far as the keeping properties are concerned, and the pathogenic bacteria that might possibly be present in the milk. The lactic acid bacteria are non-spore-bearing and are not resistant to heat. Most of them are destroyed when the milk is heated to 140° F. for fifteen minutes or to 160° F. for a moment. To insure proper keeping quality, somewhat higher temperatures must be employed, such as 145° to 150° F. for fifteen to twenty minutes.

Some types of the acid-producing bacteria that do not form spores are very resistant to heat. They grow slowly or not at all in milk stored at low temperatures, but in pasteurized milk kept at 70° F. and above, they usually dominate, and thus prevent the germination of the spores; the milk sours as though it had not been heated at all. Under commercial conditions the pasteurizing is often done in such a way, as to time and temperature, that not all the acid-forming bacteria are destroyed, or the milk may be contaminated with them subsequent to pasteurization. In such cases the acid fermentation is likely to appear, even though the milk is kept at low temperatures.

The pathogenic bacteria most likely to be present in the milk are the typhoid and the tubercle organisms. The typhoid bacillus is no more resistant to heat than the ordinary acid-forming bacteria, and all milk that has been heated, so as to impart to it satisfactory keeping properties, will certainly be free from typhoid bacilli. It has sometimes been asserted that the tubercle bacillus is very resistant to heat; some claiming that it is necessary to heat milk to 200° F. in order to destroy it. Other experimenters have asserted that lower temperatures would suffice, but the temperatures were still above those at which the milk is physically and chemically changed by the heating process. More recent work has shown that not all sources of error were avoided in the earlier attempts to determine the thermal death point of the tubercle bacillus, as, for example, it has been shown by the authors that the "scalded film" that forms on the surface of milk when heated in an open vessel will protect the bacteria imbedded in it. It has also been shown by the authors that a temperature of 140° F. for twenty minutes or 160° F. for one minute will destroy the tubercle bacilli in milk, in case the heating is done with sufficient thoroughness to insure all particles of the milk being heated to the same temperature for these periods of time.

The pasteurization of milk can be done in such a manner as to impart to it good keeping qualities and to insure its freedom from pathogenic bacteria, and yet not impair its physical and chemical properties, but much of the so-called pasteurized milk placed on the market is not treated in accordance with proper hygienic methods.

Methods of pasteurization. In order to destroy the bacteria in milk, it is necessary that the milk be heated for a varying time dependent upon the temperature employed. A lower temperature for a considerable period may exert the same effect on the bacteria as a higher temperature for a shorter time. In practice, two types of pasteurizing machines are employed, depending on the temperature at which the milk is to be treated. The discontinuous machines or intermittently operated pasteurizers are those in which the milk is heated for any desired time at any temperature. Generally, such machines consist of jacketed containers the inner receptacle being filled with milk, while the outer space between the walls is filled with circulating hot water or steam. The milk is kept agitated by the rotation of the machine. After it is heated, it is cooled in the same container by replacing the hot water first with cold water, then ice water. The disadvantage of this process is that the capacity of the machine is limited which precludes its use in places where large quantities of milk or cream are handled; for the pasteurization of limited quantities, it is very successful, as every particle of milk or cream is under the direct control of the operator and may be thoroughly and efficiently treated.

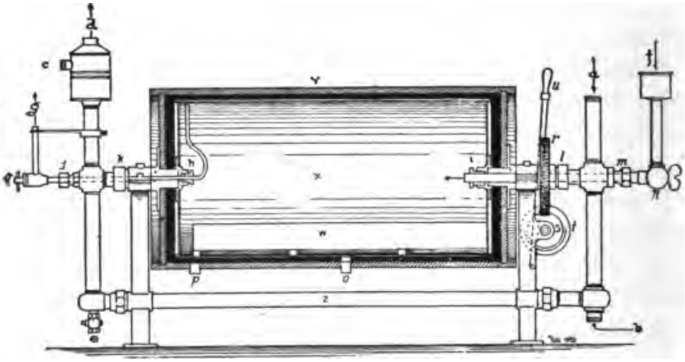

FIG. 28.—THE POTT'S DISCONTINUOUS PASTEURIZER.

The milk is placed in the inner compartment. For heating and cooling, hot or cold water is passed between the jackets.

As pasteurization was introduced for the treatment of market milk, and for the preparation of cream for butter, machines have been devised which permit large quantities, as thousands of pounds, to be handled per hour. It is evident under these conditions that the milk must be heated for only a short time, and hence a higher tem-

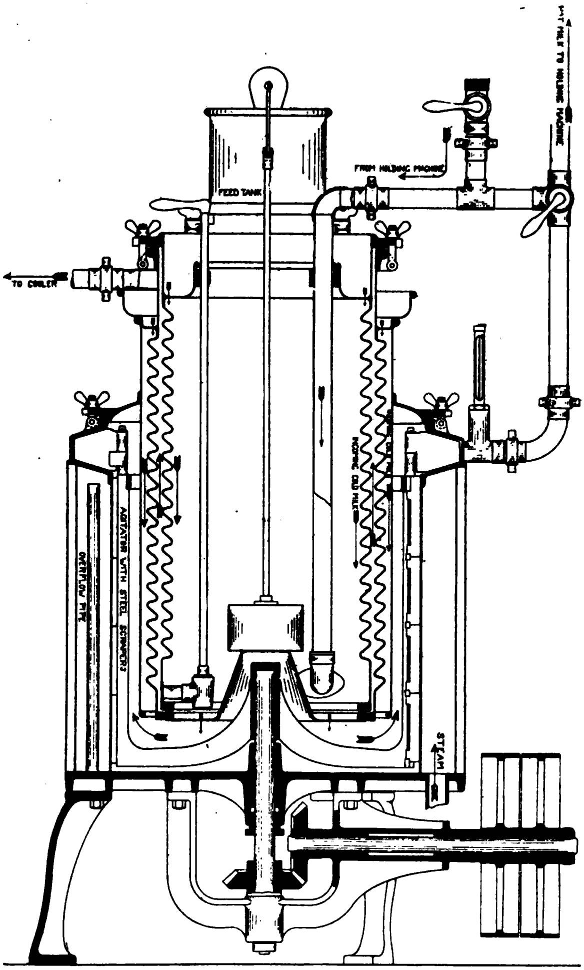

FIG. 29.—A CONTINUOUS PASTEURIZER.

The milk is exposed but a short time since it flows through the heater in a constant stream.

perature must be employed. These machines are called "continuous flow" pasteurizers since the milk passes through them in a constant stream. The period of exposure is very short, in some only a few seconds; hence, they are sometimes called "flash" pasteurizers.

All machines of this type possess the obvious disadvantage that it is impossible to heat all of the milk for a uniform period. The milk in contact with the walls of the machine flows much more slowly than in the middle of the stream, just as the current on the bank is less rapid than in mid-stream. In none of the machines yet devised have the designers been able to overcome this disadvantage. In a test of one of the most widely used pasteurizers of this type, it was found that some of the milk passed through the machine in 15 seconds, while the larger part of it was held for about 30 seconds, and some as long as forty-five to sixty seconds. If the temperature employed had been such as to destroy the bacteria in that part of the milk heated for the minimum time, hygienic safety would be assured, but in order to avoid injuring the physical properties of the milk, the tendency is to use as low a temperature as possible, so that the milk heated for the minimum time may often contain organisms that have passed through the machine uninjured.

Many devices have been proposed for the heating and cooling of the milk. In many of the pasteurizers, the milk flows in a thin stream over a metal surface, on the opposite side of which is the heating agent, usually steam; while in others, the milk is allowed to flow through a vat in which revolve a series of discs into which steam is passed. The discs are of considerable size; thus, making a large heating surface; the milk is thus heated quickly, and is constantly stirred by the rotation of the heating discs. In other types the milk passes into the bottom of a chamber in which a dasher revolves at a rapid rate. This catches the milk, throwing it in a thin film on to the wall of the chamber, which is heated with steam on the opposite side. From such machines, of which the Fjord, the Jensen, and the Reid machines are types, the milk may be forced to a considerable height. These are widely used in this country for the pasteurization of milk and cream for butter making.

Milk that has been heated must be cooled at once by the use of cold water and ice. In order to economize in the use of both steam and cooling agents, the so-called regenerative machines were devised. The essential feature of these machines lies in the fact that the cold milk inlet and the hot milk outlet are on opposite sides of a single partition; thus the inflowing cold milk is partially heated by means of the already treated hot milk which it is desired to cool.

In order to avoid the disadvantages of the continuous machines, viz., lack of control, an apparatus has recently been devised which can handle large quantities of milk, heating the same to any temperature for any desired time. In such a machine the milk is first heated in a continuous heater, and is then passed into large tanks in which it is allowed to remain for the desired time, and from which it flows over the coolers. Such an apparatus is called a "holding" machine, and is probably the most feasible type of pasteurizer now on the market, when all factors are considered. In some of the continuous machines, an attempt is made to accomplish the same result, by building the machine so that the milk requires fifteen to twenty minutes for passage through the machine, but in all such cases the same disadvantage of variation in rate of flow, as in other continuous flow type of machines obtains.

Tests of pasteurizing machines. It is possible for the operator to test the rate of flow in a machine, so as to determine whether all of the milk is heated for a uniform time. This is done most easily in the following manner: The machine is first filled with water, heating the same to the desired temperature, and regulating the rate of flow as it would be if milk was used. The flow of water is then turned off, and a stream of milk containing a known per cent of fat admitted to the machine. The time elapsing between the admission of milk to the machine, and that at which the first sign of turbidity is noted at the outlet, will be the minimum period necessary for any portion of the milk to flow through the machine. At frequent intervals thereafter, samples of the outflowing liquid may be collected, noting the time at which each sample is taken. The percentage of fat in the various samples is determined by the Babcock test; at the moment when all of the water has been removed, the sample taken will show the same fat content as the milk used. The samples taken previous to this will show a lower fat test, dependent upon the relative amount of water and milk. In this manner, the minimum, the maximum, and the average period of exposure of milk in the machine tested, can be determined with exactness.

The accompanying table gives results that were obtained in the testing of one of the continuous types of machines. The machine in question required about three hundred pounds of milk to fill it and was supposed to handle 1,000 pounds per hour. Thus theoretically it should require twenty minutes for any portion of the milk to pass through the machine. As will be seen from the data, some of the milk passed through within seven minutes after the water was shut off and the milk turned on. The figures also show that not all of the water had been replaced by the milk in even 45 minutes. In actual practice like results will be obtained, and a portion of the milk will be heated to the temperature employed but a short time. In this, the vegetating bacteria will not be wholly destroyed.

Trial	Per cent of fat in milk	Per cent of fat in milk coming from machine at following times							
		MINUTES							
		7	11	15	19	23	27	36	47
No. I	4.0	0.2	0.8	1.6	2.0	2.4	2.6		
No. II	3.8	0.2	0.6	1.5	1.8	2.2	2.6	3.0	3.4
No. III	3.5	0.7	1.9	2.4	2.8	2.8	3.0	3.4	3.4

Pasteurization of small quantities of milk. It is often desirable to treat a small quantity of milk for home use, in which case the commercial types of pasteurizers are out of the question. This treatment can be done in a number of ways, consideration always being paid to the manner of heating which should be done under such conditions, as have been shown to be necessary for efficient pasteurization. Milk may be heated in tall, narrow cans which are placed in hot water. In the household, milk may be treated by placing the filled bottle in a pail having a false bottom so the bottle shall not be broken when the pail is placed on the stove. The pail should be filled with water so that its level is about the same as that of the milk. The water is then heated to the desired temperature, maintained for the requisite period of time, and is then cooled as rapidly as possible. During the heating, the mouth of the bottle should be covered, either with an inverted glass tumbler, or the paper cap may be left in place, simply punching a small hole through it so as to permit of the insertion of a thermometer.

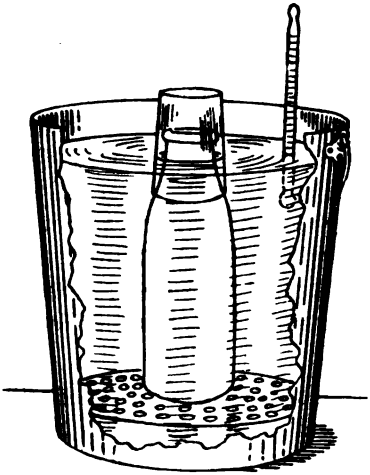

FIG. 30.—A PASTEURIZER FOR USE IN THE HOME.

A milk bottle with a tumbler for a cover. The cover prevents the formation of the "scalded layer" on the milk during the heating and also protects the mouth of the bottle from dust.

Efficiency of pasteurizing. It is easy to destroy over 99 per cent of the bacteria present by the use of any of the modern types of machines. The number remaining after treatment will be largely dependent, other things being equal, upon the number of bacteria before pasteurization. The pasteurizing process is not one by which poor milk can be changed into good milk, nor is it legitimate to use the process in place of cleanliness, as is sometimes done. There is a legitimate field for the process in the handling of market milk, as well as in the creamery; but it should be used to improve the keeping quality, and to insure the freedom of the milk from pathogenic bacteria, when other protective measures have been carried as far as possible under the prevailing conditions.

Details of process. If the process is to be successful, due attention must be given to certain details. In the treatment of market milk, care should be taken to use only that in which the acidity has not materially increased. A fair standard is about 0.2 per cent. High acid milk usually means old milk or dirty milk, either of which is very likely to contain many more spore-bearing bacteria than clean, fresh milk. The greater the number of spores, the more rapidly will the pasteurized milk spoil. If it is possible to exercise any selection of milk prior to pasteurization, the rapid test for determination of acidity will prove of great advantage.

Care should be taken to prevent fluctuations in the temperature to which the milk is heated. With varying steam pressure and variations in the rate of flow of milk, these fluctuations may be very considerable. Regulators are now made that will control the temperature within narrow limits.

In all pasteurized milk as it flows from the machine, there will remain some living bacteria. The spores will not be destroyed by any pasteurizing process, and under commercial conditions, vegetating bacteria are also present. If the milk is not quickly chilled after heating, these forms will grow, and their development is particularly hastened by the destruction of the lactic bacteria, the acid of which would otherwise hold them in check. The result is that unless immediately chilled, pasteurized milk spoils almost as rapidly as though it had not been heated at all. Efficient and rapid cooling are, therefore, as essential a portion of the process as the heating itself.

Care should also be taken to protect the milk from contamination after treatment. Every utensil with which it comes in contact should be sterilized. The bottles should be thoroughly washed and sterilized and subsequently protected from dust until used.

Sterilization of milk. It is possible to render milk sterile by the use of temperatures above the boiling point of water, where it is heated in a closed vessel, in which steam under pressure is generated. Such milk is often found in the European markets. In our own country, the only milk of this kind is the so-called "evaporated milk." In this process sweet fresh milk is evaporated in vacuum pans to about one-third of the original volume. This is then placed in tin cans, which are treated, as in the canning of such vegetables as peas and corn, by heating the milk to 230° or 240° F. for a few minutes. In this process, the bacteria (spores as well as vegetating forms) are completely killed, and the milk acquires a brownish tint, due to the caramelization of the sugar. The appearance of the product is very similar to cream, and previous to the passage of the pure food law, it was sold as evaporated cream.

Condensed milk is not wholly free from bacteria, but is sufficiently thick, by reason of its treatment so that the contained bacteria cannot grow. They remain dormant in the milk, but as soon as it is diluted to a normal consistency, growth takes place, and the milk rapidly spoils.

Condensed milk is prepared by adding cane sugar to fresh sweet milk, then evaporating the mixture to one-third the original volume, forming a semi-solid product. Syrups owe their keeping qualities to the same factor, as condensed milk, *i. e.*, the high consistency.

Milk is also preserved by wholly evaporating the water, thus leaving a dry powder, which on being mixed with water again will have much the same properties as the original milk. Various methods have been devised for the preparation of these milk powders, all of which have been patented by the inventors. If the powder is to be kept for long periods, skim milk must be used, since the fat slowly undergoes changes which cause it to have a rancid odor. These dry preparations are largely used by bakers in place of fresh milk.

CHAPTER VII.

BACTERIA AND BUTTER MAKING.

In the making of butter it is necessary to concentrate the milk fat into a small volume. This process, known as creaming, may be accomplished by gravity, if the milk is allowed to stand undisturbed, the fat globules rising slowly to the surface. Much more rapid separation may be secured, by placing the milk in a rapidly revolving container in which it is subjected to centrifugal force, which causes the heavier parts of the milk to pass to the outside of the bowl, while the lighter part, the fat, collects at the center of the revolving bowl. There are an enormous number of fat globules in milk, over 5,000,000,000 in each cubic centimeter, and as these move through the milk serum, they carry with them many of the bacteria. The cream is thus much richer in bacteria than is the skim milk, or even the milk before separation. Besides the mechanical separation in the manner described, the method of creaming is of importance, in determining not only the number but also the kind of bacteria in the cream.

Methods of creaming. In the shallow-pan method of creaming, the milk is kept at ordinary air temperature. This temperature favors especially the growth of the acid-forming bacteria. The milk is usually sour by the time the cream is removed from it; consequently, the bacterial content of the cream is high. Moreover, the cream is exposed to air contamination, and is thus seeded with molds, and those forms of bacteria that are always found in the air. The cream obtained in this manner is likely to contain not only numerous bacteria, but a great variety of forms, some of which undoubtedly are the cause of the poor keeping qualities of butter made from such cream.

In the more modern method of gravity creaming, in which the milk is placed in deep narrow cans kept in cold water, the conditions are not favorable for the growth of acid-forming bacteria. If the milk is produced under clean conditions, and is placed in cold water at once, the bacterial content of the cream will be low, and it will be less likely to contain undesirable forms than the cream which is obtained from the shallow pans.

In separator cream the bacteria will be represented by the kinds present in the milk at time of separation. If this milk is quite old, the cream will contain large numbers of bacteria; if, however, early separation is made and the milk is clean, the bacterial content of the cream will be low.

Types of butter. Butter may be divided into two types—acid or sour-cream, and sweet-cream, depending upon whether the cream is allowed to undergo the acid fermentation or not before it is churned. In southern Europe, it is the custom to churn the cream as sweet as possible, and the resulting product possesses only the natural, or primary milk flavor. To one accustomed to butter made from sour or ripened cream, this taste is flat, and if the butter is free from salt, may remind one of grease. Sweet-cream butter has a delicate flavor when it is made from good milk, and the taste for it is rapidly acquired. In some centers, as in Paris, the market demands this type of butter quite exclusively.

If the cream is allowed to undergo the acid fermentation before churning, the butter has a much higher degree of flavor and one that differs materially in kind. Under primitive methods, it was difficult to keep the cream sweet until it could be churned. On the small farm with gravity creaming in shallow vessels and infrequent churning, the cream was certain to be sour when churned. Undoubtedly, the making of butter from sour cream came into use because of its greater convenience; people became accustomed to sour-cream butter, and at the present time it is used in the greater part of the world, and is the type made in all of the great dairy countries.

Ripening of cream. In modern dairy practice the souring of the cream is called the *ripening* process, and is, where the best methods are employed, largely under the control of the butter maker. The changes that go on in the ripening process are the same as have been discussed in the acid fermentation of milk. The increase in acid is accompanied by an enormous increase in the number of bacteria; the ripe cream will contain hundreds of millions of bacteria in each cubic centimeter. The effect of this germ life is to improve or injure the butter, depending upon the class of bacteria to which it belongs. The problem of the modern butter maker is to control the kinds of bacteria growing in the cream.

The temperature at which cream is held during the ripening process is favorable to the growth of the acid-forming bacteria; hence, in ripe cream, they are practically the only kind of bacteria to be found. It must be remembered, however, that there are different classes of acid-forming organisms, some of which produce desirable flavors, while others are distinctly harmful.

The intensity of flavor of butter is, in a general way, directly related to the amount of acid that is formed in the cream. A low acidity at time of churning is usually associated with a mild flavor, while a higher degree of acidity, up to a certain point, imparts a more pronounced flavor to the product. If cream is overripened, the quality of the flavor is seriously impaired.

In determining the acidity of cream, a definite volume is taken, and the acidity determined by titration, expressing the results as such a per cent of lactic acid. Manifestly, the amount of fat in the cream influences the apparent per cent of acidity. The acidity will not usually exceed 0.5 to 0.7 per cent, but in reality the serum will contain more than this, as the acid is formed in the serum, the butter fat having no role whatever. In a very rich cream, 40 to 50 per cent fat, it is impossible to develop more than 0.4 to 0.5 per cent of acidity, and the flavor of the butter will be low, because of the relation between the amount of acid and fat, while in a thin cream having the same acidity, the ratio between the amounts of fat and acid will be very different. For example, in 50 per cent cream of 0.5 per cent acidity there will be one-half pound of acid in one hundred pounds of cream and fifty pounds of fat; in a cream containing 20 per cent of fat and having an acidity of 0.5 per cent there will be one-half pound of acid to twenty pounds of fat. The flavor of the butter from the rich cream will be quite different from that made from the poorer cream.

The acidity of cream cannot be determined with any degree of accuracy by the taste or odor. Every butter maker should have some method of determining the degree of acidity in his cream, so that he may better control the production of flavor in his product. Several methods have been devised for this purpose and the necessary apparatus is sold by all dairy supply houses.

The effect of the ripening of the cream is shown not only in the flavor of the product, but in a number of other ways. Sour cream churns more easily, and more exhaustively than does sweet cream. It is supposed that the fat globules are surrounded by a film of albuminous material which prevents their coalescing readily. During the ripening process, the action of the acid apparently dissolves this enveloping substance, and the globules cohere more easily in the churning process.

Ripened-cream butter keeps better than sweet-cream butter. In sweet cream there are few lactic bacteria, the majority of the bacteria present being of various kinds, many of which may be injurious, so far as the keeping quality is concerned. In sour-cream butter the lactic bacteria make up over 99 per cent of the bacteria present, and their presence tends to prevent the development of undesirable non-acid forms.

Source of butter flavor. The flavor of ripened-cream butter has been shown to be directly connected with the acid-fermentation of the cream. The amount of lactic acid formed from the sugar fermented is dependent upon the kind of bacteria present. The acid-producing organisms that are desirable from the standpoint of the butter maker, form comparatively small amounts of other by-products, but these undoubtedly affect the flavor of the butter. As fats have the power of absorbing odors, the butter fat absorbs some of the by-products of the acid fermentation, thus acquiring a certain aroma and flavor.

It is not necessary that the cream be ripened, in order to have the fat acquire a flavor, for if sweet cream is churned with a considerable proportion of sour milk, the butter will have much the same flavor, both as to intensity and kind, as though the cream had been allowed to sour naturally. A process of butter making known as the LeClair method is based on this principle. The flavor-producing substances can also be absorbed by the butter after it is churned, by working the butter in contact with sour milk. Attempts have been made to add pure lactic acid to the cream, instead of allowing the acid to be formed by the bacteria, but while the physical effect on the cream is the same, the flavor and aroma of the butter are deficient, because the acid itself does not supply the necessary aromatic products. This emphasizes the importance of the by-products of the acid fermentation other than the lactic acid.

In the past numerous attempts have been made to find organisms that might be added to the cream, in order to produce the delicate flavor characteristic of the best type of butter. Some bacteriologists have claimed that the source of the flavor-giving substance was to be found in the decomposition products of the nitrogenous constituents of the milk. None of these attempts have stood the test of practical use in creameries, and it has been demonstrated that the finest type of butter can be made by the use of lactic bacteria alone. Formerly, when butter was made wholly from cream soured under natural conditions, a much higher degree of flavor was developed. Under present market demands, a less pronounced flavor is desired, a condition more readily met by the use of modern methods.

Importance of butter flavor. The importance of flavor in determining the commercial value of butter is evidenced by the relatively high value placed upon this factor in scoring, viz., flavor, 45 points; body or texture, 25 points; color 15; salt 10; and package 5 points. The factors on which butter is judged, are with the exception of flavor, wholly under the control of the maker, but as the production of flavor is dependent on the kind of bacteria present in the cream, it is a far more difficult matter to control, and yet it is of the utmost importance in determining the value of the product.

The flavor of the butter is dependent on the quality of the cream. If this is dirty and sour, the maker has little control over the type of fermentation, and hence, little control of the flavor of the butter. This has led in some cases to the grading of the cream, basing the division on the acidity, flavor, and fat content. Such practice is entirely justifiable, as a better quality of butter can be made from fresh, sweet cream than from that already fermented. It is noteworthy that the quality of butter has not improved since the introduction of the centralizer system, in which cream is shipped for long distances.

Control of the type of fermentation. In the older methods of butter making, there was little or no control of the type of fermentation that took place in the cream. Where milk is produced under clean conditions, and kept at ordinary temperatures, it will generally undergo fermentation changes, due to the desirable type of acid-forming organisms. In milk, which is less carefully handled, the undesirable bacteria are more abundant and the quality of the butter of lower grade. When butter was made on the farm, before the development of the factory system, it was not a question of vital importance whether the product was uniform from day to day, but with the advent of the modern creamery, turning out thousands of pounds of butter per day, and with the extension of the markets for the product, the question of uniformity came to be of much importance. A uniform product can be secured only by the control of the type of fermentation in the cream, or by the control of the kinds of bacteria that cause the souring of the cream. Modern methods of butter making have been devised on the basis of an improvement in the ripening process.

Starters. From the earliest practice of allowing the cream to stand until sufficient quantity had accumulated for churning, it was only a step, but a most important one, to the addition of sour milk, sour cream, or buttermilk, to hasten the ripening process. This was the beginning of the modern starter. Experience demonstrated that the addition of these already fermented liquids. exercised a desirable effect upon the production of butter flavor, even though, at that time, the phenomenon of milk fermentation was not satisfactorily understood, and the relation of bacterial by-products to the production of flavor in butter was not recognized.

As a result of experience alone, improvements in the development of the "home made" starter took place. By careful selection of clean milk, and the natural fermentation of this under carefully controlled conditions, as well as the control of the temperature of the cream during the ripening, improvement in the technique of cream ripening gradually developed. More and more attention was given to the preparation of the starter, and its propagation from day to day, under conditions which would prevent its deterioration. This method of utilizing naturally fermented milk or cream was gradually extended, until it became almost universal in the larger butter-producing districts.

In 1890 a more refined and scientific process was introduced by the Danish bacteriologist, Storch. Recognizing the fact that butter flavor was attributable to the development of the bacteria present in the ripening cream, he conceived the idea of isolating the various types of organisms found in milk and testing them as to their effect on the quality of flavor. Selection was then made of the most favorable flavor-producing types, and these were propagated in suitable media, such as skim milk, which was rendered more or less perfectly sterile by pasteurization or sterilization. Under such conditions the addition of a selected ferment could be made to the fresh cream, and so control the type of fermentation which occurred therein. An essential requisite in any organism used for this purpose must be the ability to produce relatively large amounts of acid rapidly at ordinary ripening temperatures, and also to form sufficient quantities of the proper flavor-producing substances to impart a suitable flavor to the butter fat. Such starters are known as pure culture or commercial starters, and are prepared in both liquid and dry form. At present they are used to a greater or less extent in all of the leading dairy districts.

Liquid starters consist of a mass of sterile nutrient medium, milk or beef broth, inoculated with the pure culture. The dry starters are made by adding liquid cultures, containing the growing bacteria, to some absorbing material, such as milk sugar, milk powder, or starch, the whole mass being dried at low temperatures, so as not to injure the bacteria. Under such conditions the bacteria exist in a dormant state, and are protected from their own by-products, to which they would be exposed if maintained in liquid cultures. The keeping quality, therefore, of dry cultures, is much better than that of liquid cultures.

By the use of the pure-culture starters, the butter maker is able to add to his cream the same kind of bacteria from day to day, and the butter will be more uniform than when the less constant home-made starter is employed. In cream to which the starter is added, there are present a greater or less number of acid-forming bacteria, depending upon the age of the cream, and upon the condition under which it was produced. These will grow during the ripening process, and the flavor of the product will be the result of the mixture of the bacteria in the cream. The maker can not, therefore, be certain that the addition of a pure culture to fresh cream will effectively control the type of fermentation. This can be secured only by first destroying the existing bacteria in the cream, before the selected culture is added. Heating the cream accomplishes this; and in cream thus freed from the various kinds of bacteria, the butter maker can insure the dominance of the desirable types, contained in the pure-culture starter. If the cream can be obtained in a sweet condition, the maker through this process of pasteurization, and the use of pure cultures, secures almost perfect control over the type of fermentation that occurs in the cream, and thus exercises control over the degree and kind of flavor of the product. This most scientific type of butter making is now used by the most progressive butter makers in the leading butter-producing regions of the world.

Pasteurization of the cream also distinctly improves the keeping quality of butter, a condition doubtless due to the freedom of the same from organisms other than the lactic bacteria. This is a factor of as much importance as uniformity, because under modern business conditions, the surplus production must be kept in storage, and it is essential that the quality should not deteriorate materially during this time.

Process of pasteurization for butter making. In the pasteurization of market milk, it is necessary to take into account the effect of heating on the physical and chemical properties of the milk, and the degree of heat that can be employed is limited. In pasteurizing cream for butter, there is no such limitation, and the cream may be heated to any temperature desired. In Denmark where the process of pasteurization has been used most extensively, temperatures ranging from 176° F. to 190° F. are used. The machines are of the "continuous flow" type, and the cream rather than the whole milk is treated. To prevent the spread of tuberculosis and other diseases, the Danish government requires that all cream and milk be heated to 176° F., before the skim milk or butter milk is returned to the farms.

The heating of the butter fat to high temperatures has an injurious effect on the texture of the butter, unless the cream is cooled to 50° F., for a period of at least two hours previous to churning.

Propagation of starters. As has been previously shown, the quality of butter depends on the kind of bacteria in the cream or in the starter added. The commercial starters contain lactic acid bacteria that have been selected with especial care; most of the starters now sold contain but a single kind of bacteria; hence, are often called pure-culture starters. The package purchased contains but a small quantity, and before the starter can be used in the ripening of cream, it must be increased in amount. It must also be propagated from day to day so that a fresh starter shall be available daily for addition to the cream. The propagation of the starter must be done with especial reference to keeping it in good condition and in as high a state of purity as possible.

In the past the starter was propagated, by adding the contents of the bottle purchased to a small amount of milk that had been heated and cooled; this, if kept in a warm place, would be curdled in twenty-four hours, and could be used for the inoculation of a large mass of milk, that had been treated in a like manner, and which, when curdled, was added to the cream; a small amount was saved for the purpose of again inoculating a mass of milk that had been heated and cooled. Following this method it was very difficult to keep the culture from becoming contaminated with other forms of bacteria. More recently the most successful butter makers have propagated the so-called "mother starters" in small vessels, and have used the larger mass of starter for the inoculation of the cream alone.

Glass vessels are preferable for the propagation of the mother starters since they are impervious and through the transparent wall the condition of the ripened starter can be more easily determined than in a metal or earthenware vessel. An ordinary milk bottle with an inverted tumbler for a cover, to protect the starter from contamination from the air, is a most convenient vessel.

The starters may be propagated either in whole or skim milk; the former is preferable since, in most creameries, it can be more easily selected. The quality of the milk used has much to do with the quality of the starter; it should be as fresh and clean as it is possible to obtain. The clean bottle should be filled half to two-thirds full, covered and heated in some manner so that the milk shall be at a temperature close to the boiling point for fifteen to twenty minutes. The heating may be done by placing the bottles in water, which is heated on a stove or by steam, or the bottles may be subjected to streaming steam. The milk is cooled quickly and the contents of the package purchased added and well mixed with the milk. In the case of the dry starters, the mixing should be done with especial care. The bottle is kept in a warm place and in twenty-four to thirty-six hours, the milk should be curdled. A second bottle must be treated as before and inoculated from the first, and the process repeated daily since the bacteria must have fresh food, if they are to be maintained in good condition.

It is desirable to use starters soon after curdling has taken place. In order to accomplish this, the maker must be able to maintain constant conditions from day to day, especially with reference to the amount of the ripened starter that is transferred to the fresh bottle of milk, and the temperature at which the bottles are kept. A spoon, arranged as shown in Fig. 31, enables one to carry a definite amount of the ripened starter to the bottle of milk to be inoculated and a constant temperature box (Fig. 32) permits of the maintenance of the same temperature from day to day. Through careful supervision of these points, and by taking care at every step to avoid the introduction of contaminating organisms, the purity of the culture can be maintained, and the bacteria kept in a healthy condition, by not allowing the acid to reach a point that will injure or weaken them.

The starter is used because of the acid-forming bacteria it contains; it is said to be ripe and in the best condition for use at the time it contains the greatest number of living bacteria. It has been found by experiment that this is at the time the milk curdles at ordinary temperature, or when the acidity is about 0.6 per cent. If the acidity is allowed to increase to 0.8 or 0.9 per cent, the number of bacteria will be much less and a larger

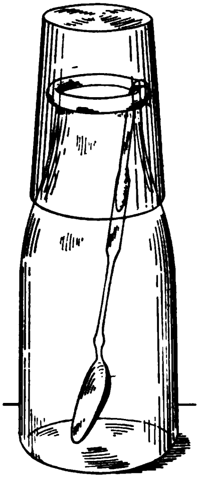

FIG. 31.—BOTTLE FOR MOTHER STARTERS.

A milk bottle with a tumbler for a cover and a spoon for inoculating the other bottles enables the butter maker to propagate the starters without contamination.

amount of the starter must be used in order to ripen a definite amount of cream in the desired time. The use of an overripe starter also has an injurious effect on the flavor.

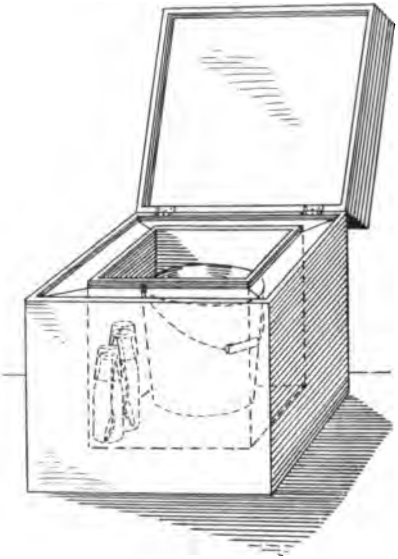

FIG. 32.—AN INCUBATING CHAMBER FOR STARTERS.

The inner compartment will hold a pail of water and the bottles for the mother starters. The temperature can be kept at any desired point by the use of warm or cold water. The four-inch space between the walls is filled with hay or mineral wool.

The ripened starter should be perfectly homogeneous, showing no bubbles of gas or free whey; the odor should be agreeable and the acid taste mild; on shaking, the curd should break up into a smooth creamy liquid free from lumps. This is especially important in the starter that is to be added to the cream, since otherwise the starter cannot be uniformly mixed with it and white specks of curdled casein will be noted in the butter.

The firmness of the curd is not so dependent on the amount of acid formed as upon other factors. If the curd shrinks to any extent and the whey is expressed, it is certain to produce a starter that will contain lumps that cannot be broken up. With a pure culture of lactic bacteria, there is little difficulty in this regard, but as soon as gas-forming bacteria are introduced, trouble is likely to result.

In the propagation of starters, it is always to be remembered that the bacteria, although invisible to the eye, are living things, and unless conditions are favorable in every particular, it is impossible to keep them in a healthy condition, so that growth in the cream is rapid, producing the acid demanded for churning, and imparting to the butter the desired flavor, both as to degree and kind. No part of the daily routine of the butter maker should be performed with more care than the preparation of the starters, both the mother starters, and the larger one for addition to the cream. The latter can best be made in one of the many forms of starter cans now on the market, since by their use, the maker can heat and cool the milk with little trouble, and can maintain the starter at any desired temperature. Better starters cannot be made in them than by the use of simple and improvised apparatus, but better results can be obtained with the same expenditure of time and labor.

In the handling of the large starter, care should be used not to overripen, since the larger quantity is more likely to "whey off" than is the smaller starter. Skim milk rather than whole should be used for this. It should be selected with care and heated to 200° F. for thirty minutes. The inoculation and the temperature should be so controlled, as to ripen the starter at the time it is to be needed. These conditions must be determined by the maker for himself. It should be remembered that the bacteria grow much more rapidly, as the temperature is increased; and hence, the amount of inoculation is dependent on the temperature at which the starter is to be kept.

When the starter is propagated under practical conditions, it sooner or later deteriorates, either in acid production, or in flavor, and a new pure culture must be procured from the manufacturer. It is impossible to give a hard and fast rule as to the length of time a starter can be kept in good condition. It will depend on how well the maker satisfies the conditions necessary for maintaining its purity and strength. The use of imperfectly sterilized milk, or dirty utensils soon contaminates it; overripening injures flavor production. One of the most frequent troubles encountered is the appearance of a slimy or ropy condition in the starter, although the acidity developed may be normal and the flavor desirable. It has been found that this condition is not necessarily due to contamination, as was considered true in the past, but rather to some change in the lactic bacteria themselves. If the propagation is continued, the slimy condition will usually disappear.

Starters in "process" butter and oleomargarine. The advance which has recently been made in the science and practice of cream ripening and butter production is utilized most effectively in the treatment of cream in the renovating process. Old, soured, and stale cream is reduced in acidity by the addition of lime. The cream is then pasteurized and aerated to expel the odors as much as possible. A large amount of starter is then added and the cream immediately churned. Under these conditions, the bad flavors are materially reduced in intensity, and desirable flavors absorbed by the fat from the selected starter used. It is thus possible to produce butter of good quality from cream that would at first be regarded as quite unsuitable for butter production.

In the manufacture of oleomargarine the same principle is utilized. The butter aroma and flavor is imparted to the neutral oils and tasteless fats by churning the same in contact with a properly prepared starter. Renovated or process butter is given a desirable flavor in the same way.

Wash water. It has been found that the purity of the water used in washing the granular butter has a marked influence on the keeping quality. If the water is from a shallow well into which surface water finds its way, it is certain to contain large numbers of those types of bacteria that are found in the soil, while if it comes from a deep well that is properly protected from surface contamination, the bacterial content of the water will be low and no injurious effect on the butter will be noted. When it is impossible to obtain pure water for washing purposes, a proper supply may be secured by sterilizing the water. The most convenient way of heating the water is by the direct injection of steam. It is necessary to use that coming directly from the boilers and not the exhaust from the engine, since the latter is likely to contain small amounts of oil that will impart to the butter an objectionable flavor. After cooling the water is ready for use. It has been shown that the cost of treating an impure water is more than covered by the increased returns from the product.

A pure and healthful water supply should be one of the essential things of every dairy, creamery, and cheese factory, not only for the sake of the quality of the product, but also to avoid contamination of products with disease-producing bacteria.

Bacteria in butter. The germ content of butter will depend on the type of cream. Sweet-cream butter contains but few bacteria. In sour-cream butter, the content in bacteria will be greatly increased, especially as to lactic organisms. Often, it may amount to several millions of organisms per gram. The germ content of butter is greater on the outside of a package than within the mass, due doubtless to the free access of air, thus favoring the growth of the aerobic forms.

The composition of normal butter does not favor the growth of the majority of kinds of bacteria that are contained in it. The washing process removes much of the material suitable as food for the bacteria, such as sugar and albumen. If considerable butter milk is left in the butter, the growth of bacteria will be quite rapid, at first, but does not continue for any considerable length of time. The addition of salt also tends to restrain the growth of most kinds of bacteria.

Keeping quality of butter. Butter is at its best when fresh from the churn. Storage does not improve its flavor; on the other hand, deterioration in quality gradually occurs, depending in the main on the temperatures at which it is kept. If held at low temperature (0° F. or below), it will keep unchanged for months, but deterioration ensues rapidly upon removal. At ordinary chilling temperatures, 40° to 50° F., deterioration is more rapid. This relation to temperature indicates that the keeping quality of butter is apparently related closely to the biological factors present.

This condition is still further accentuated by the fact that the keeping quality of the product is profoundly affected by the quality of the cream. Butter made from sweet, fresh cream, that has been thoroughly pasteurized, has the best keeping quality, while butter made from such cream, but not pasteurized, has the poorest keeping quality, especially when no salt is added. Every process by which the desirable lactic bacteria are increased in proportion to other kinds has a marked effect in enhancing the keeping quality of the butter. Thus, the use of pure cultures in raw cream, and pasteurization together with the pure cultures, have a marked beneficial effect.

The addition of preservatives exerts a marked effect on keeping quality. Borax is the chemical most frequently employed for this purpose. Its use is allowed in Australia and New Zealand in butter that is shipped to England, but the use of all preservatives is forbidden in the United States.

The size of the package also has an effect on the keeping quality; the smaller the package, the greater is the surface exposed to the air and the more rapidly the butter deteriorates. Butter used in the United States Navy is packed in hermetically sealed cans so as to exclude the air as far as possible.

From the fact that any condition which restrains or inhibits the growth of micro-organisms has a tendency to improve the keeping quality of butter, it would appear that the detrimental changes in the quality of butter are due to biological causes. The most common defect known is that usually referred to as rancidity. There are, however, different types of changes that are probably included under this head and it is very probable that different causes are operative in their production. True rancidity is probably due to biological causes; the so-called tallowy change, in which the butter acquires the odor of tallow is probably due to the combined action of light and air on the fat.

Bacterial defects in butter. There are a number of defects in butter that are positively known to be due to the growth of bacteria in the milk or cream, or in the butter itself. The lack of flavor is looked upon as a defect in the case of ripened-cream butter. It may be due to insufficient ripening of the cream, or to the lack of acid-forming bacteria that produce the desirable flavor-forming compounds. Not all acid-forming bacteria are able to produce favorable, flavor-forming compounds; hence, sour cream butter may sometimes be deficient in flavor by reason of this fact.

Putrid butter. This specific butter trouble has been observed in Denmark, where it was first studied by Jensen. Butter affected by it rapidly acquires a peculiar putrid odor that ruins it for table use. Sometimes this flavor may be developed in the cream previous to churning. It may be caused by a number of bacteria.

Turnip flavored butter. Butter sometimes acquires a flavor resembling turnips. This trouble may be due to the feeding of such roots, the aromatic substances peculiar to them being absorbed directly by the milk and thus transferred to the butter. Weigmann traced a similar flavor to certain bacteria that entered the milk from barn filth.

Cowy odor in butter. There is sometimes to be noted an odor in butter as in milk that resembles that of the cow stable. Usually this defect has been ascribed to the absorption of these odors directly by the milk. Organisms have also been described that impart to the butter a very similar odor. Bitter butter may be due to the feed that is consumed by the cow, or it may be due to those forms of bacteria that produce a bitter fermentation of the milk.

Fishy butter. One of the defects that has attracted a great deal of attention recently is known as fishy butter. Such butter has the odor of herring brine. A large amount of work has been expended in attempting to discover the cause but without much success. Rogers claims that it is connected with the acid fermentation, and that it is not noted in sweet-cream butter. The air has also some effect according to the same investigator.

Moldy butter. A defect that causes a great amount of loss is the development of mold on the surface of the butter, either in tubs or in prints. This trouble is easily prevented. Butter is not well suited to the growth of mold, but the paper used for lining the tubs, or wrapping the prints is an excellent medium for mold growth. The wood of the tub also furnishes ample food for this type of life, especially where the wood contains any sap. One other essential condition for mold growth is a supply of oxygen. The mold spores are widely disseminated, and are always to be found on the butter tubs and on the paper. The number is not likely to be sufficient to cause trouble unless the tubs and paper have been kept under such conditions, as to allow growth to take place on them before use. During damp, hot weather, the amount of moisture absorbed by these materials is often sufficient to allow molds to grow on them. This trouble can be prevented by the storage of tubs and paper in a clean dry place, or by a disinfecting treatment which will destroy the mold spores. The most successful method of treatment of tubs is to apply paraffin to the inner surface, which can be easily done by the use of some one of the various machines now on the market. The thin layer of paraffin excludes the moisture from the wood, and also prevents the mold from obtaining a supply of oxygen for its growth. The tubs may be steamed, treated with hot water, or filled with a dilute solution of formaldehyde, and allowed to stand overnight. Soaking in brine as is usually done in the creameries is of some effect, but will not completely kill mold spores.

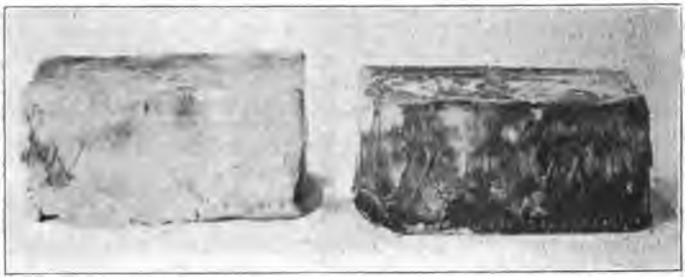

FIG. 33.—MOLDY BUTTER.

The mold grows on the paper in which the butter is wrapped rather than on the butter. The print on the left was wrapped in the same paper as the print on the right except that the parchment cover had been steamed for a few moments.

Butter may mold where the tubs have been thoroughly treated, because of the mold spores on the paper used for the lining. One of the black molds is able to thrive on parchment paper whenever the air is damp. In the past but little attention has been paid to the paper as a source of trouble. It is certain that it is often at fault, and that as much attention should be paid to the paper as to the tub. A most efficient way of treating paper, either for tub liners or print wrappers is to place same in boiling water for a few minutes.

CHAPTER VIII.

BACTERIA AND CHEESE MAKING.

Butter, such as that of the sweet-cream type that is highly esteemed in many parts of the world, may be made without the aid of bacteria, but no important kind of cheese can be made under commercial conditions without them.

Types of cheese. Cheese consists of the fat and the precipitated casein of milk, together with a large amount of water and the salts found in milk. The numerous types of cheese may be divided into two groups, depending on the manner in which the curdling of the milk is brought about. Sour-milk cheese is made from curd, formed as a result of the acid fermentation of the milk. Thus, at the very first stage in the making of this type, the importance of bacteria is apparent.

The second type is that made from curd, which is precipitated by the addition of rennet to the milk. This type may also be divided into two groups, depending upon their texture; the hard cheese, and the soft cheese. The ordinary cheddar, the common American type, is the most important example of the hard cheese; Limburger, of the soft cheese. Cheese are designated as hard or soft, depending upon the amount of whey that is retained in them during the making process. The moisture content has an important influence on the type and amount of life that develops on and in the curd mass, and as will be seen, the ripening and flavor of the cheese are dependent upon these biological factors.

The two groups of hard and soft cheese have no sharply defined limits, but merge into each other. The extreme types of the hard cheese are so dry and firm that they can be cut only with difficulty. Such cheese are used primarily as condiments to impart a flavor to certain dishes, as marcaroni, and for this purpose are grated. The extreme type of soft cheese is a soft, pasty mass that can be easily spread with a knife.

Hard cheese, because the ripening process goes on uniformly throughout the entire mass of cheese, may be made of any size which permits of commercial handling. They can also be kept for long periods and preserve their good qualities. Soft cheese are made in small sizes, since on account of their consistency, they could not otherwise be handled, and also because of the manner of ripening. The ripening is due to the action of organisms developing on the surface, the by-products of which diffuse into the curd. If the cheese are too large, the outer layers become overripe, while the interior remains more or less unchanged, or insufficiently changed. Soft cheese mature much more rapidly than hard cheese; consequently they are short lived.

Although made from the same substance, milk, it is noteworthy that there are over four hundred varieties of cheese produced. Most of these find only a local market where made. Less than a dozen varieties are to be regarded as general articles of commerce.

Quality of milk. In the making of butter there are a number of processes that the maker can use when he finds himself obliged to utilize poor milk. The milk can be pasteurized and the harmful bacteria thus destroyed;

desirable kinds can then be added in the form of a pure-culture starter. Pasteurization also drives off some of the volatile by-products of the first acid fermentation. By the use of these means, the maker can prepare a very good product from poor material.

In the making of most kinds of cheese, especially those of the greatest commercial importance, the cheese maker can call to his help no such aids, but must use the milk as it is brought to him. It is possible to prepare certain kinds of soft cheese from pasteurized milk that differ in no essential point from the same cheese made from raw milk. Hard cheese are also made from pasteurized milk, but in most cases such cheese differ, especially in the degree of flavor, from that made from unheated milk. It is quite probable that, as the factors concerned in the ripening of cheese become better known, methods will be evolved for the successful production of many kinds of cheese from pasteurized milk.

It has been shown that the quality of milk is almost wholly dependent upon the number and kinds of bacteria it contains. These bacteria pass into the cheese, and there produce the same products as they would have done in the milk itself. In butter making, practically all processes are under the control of the maker, until the product is ready for the market; but cheese, on the other hand, passes through a complicated series of changes after it has left the maker's control. During the manipulation of the milk and the curd in the vat, he can exert some influence on the quality of the product, but he is much more dependent on the quality of the milk than is the case in butter making.

Every effort should therefore be made to furnish to the cheese maker the quality of milk from which he can prepare fine cheese. In other words, the milk should be produced under clean conditions and carefully cooled and handled until delivered to the maker. Poor milk from a single farm may have such an effect upon the cheese made from the milk of twenty farms as to depreciate the selling value of the entire product several cents per pound.

The tests that have been previously described (p. 99) have been devised especially for the testing the quality of the milk for cheese making purposes, and are of the greatest service to the maker in tracing the source of poor milk.

Cheddar cheese. The first step in the making of cheddar cheese is the "ripening" of the milk, or the development of a small amount of acid. In this fermentation, the development of acid is preceded by an enormous increase in the number of acid-forming bacteria. Milk for cheese making should show an acidity of about 0.2 per cent or slightly more than in fresh milk. In other words, the maker wishes the milk to be in such condition, bacteriologically, that if kept at a temperature favorable for the growth of the acid-forming bacteria, the acidity will increase rapidly.

The curdling of the milk to precipitate the cheese solids is produced by the addition of rennet, which is obtained by extracting the fourth stomach of the young calf with a solution of common salt. In the past the maker prepared his own rennet solution from the dried stomachs ("rennets"), but at present, the extract is prepared commercially, in a much more uniform manner. The rapidity of the curdling is dependent upon the acidity of the milk. In order to secure proper rennet action, a slight increase of acid over that found in fresh milk is usually necessary; thus at the very beginning of the process of making cheddar cheese, the bacteria are of importance.

As the milk curdles, the bacteria are enclosed in the curd as are the fat globules. The curd is cut into small fragments by means of a curd knife, and as the mass is warmed, the acid develops, causing the curd particles to shrink, thus expressing the whey. Within a short time, the volume of the curd is not more than one-eighth that of the milk, but in the curd are held over 90 per cent of the bacteria of the milk. To secure rapid curdling in the vat, the milk is warmed to 85° to 90° F., a temperature that is most favorable for the growth of the lactic bacteria. Since there is a large number of bacteria concentrated in a small volume, and the temperature, as well as all other conditions, is favorable to growth, multiplication of the bacteria goes on rapidly, and as a consequence, acid is formed in large amounts, as is shown by the following figures given by Publow for the manufacture of the export type of cheddar cheese:

Acidity of milk before adding rennet	.2 to .21	per cent
Acidity of whey before heating curd	.14 to .145	"
Acidity of whey before removing from curd........................	.16 to .18	"
Acidity of whey coming from the curd after removal of whey and curd is packed..................	.24 to .30	"
Acidity of whey coming from curd before milling....................	.65 to .75	"
Acidity of whey coming from curd before salting....................	.90 to 1.10	"

If the milk had been kept at the same temperature as the curd, the acidity would have increased much more slowly since the acid would have been distributed through a larger volume. In the cheese curd the same amount of acid is probably formed, as would have been produced in the total amount of milk during the same interval.

The acid produced by this bacterial activity has a most marked effect on the curd. At first the curd masses are tough and firm, the particles showing no tendency to adhere to each other. As the acid increases in amount, the curd becomes plastic, the outer surface of the particles adhering or "matting," as the maker expresses it. The result is a solid coalescent mass of curd, which is cut into small pieces, *i. e.,* "milled," before it is put to press. The acid allows the blending of the pieces under the influence of the pressure so that a cheese is one single mass. Under certain abnormal conditions, the development of acid may be interfered with and the particles of curd fail to mat, in which case, the cheese will be crumbly when it is cut. The determination of the proper time for pressing is made by the application of what is known as the hot iron test. This is made by determining the length of the "strings" or "threads" which can be drawn from a mass of curd when it is brought in contact with a hot iron at a cherry red heat, the length of the curd threads being a measure of the amount of acid that has been formed in the curd.

The rate of acid formation within the curd particles is also measured by determining the acidity of the whey as it comes from the curd at different stages in the making. This test, which is often used in place of the "hot iron" test is carried out in the same manner, as in determining the acidity of milk or cream. The quality of the cheese, both as to texture and flavor, is dependent to a great degree upon the amount of acid that is formed during the various stages in making; hence, the successful maker must follow closely by some means the acid formation in the curd until it is put to press.

It is very necessary that the milk shall contain a sufficient number of acid-forming bacteria to produce the required amount of acid. If a sufficient number of bacteria are not present in the milk as it is received, as is the case with very sweet milk, they must be added by the maker in the form of a starter, or the process of making will be much prolonged.

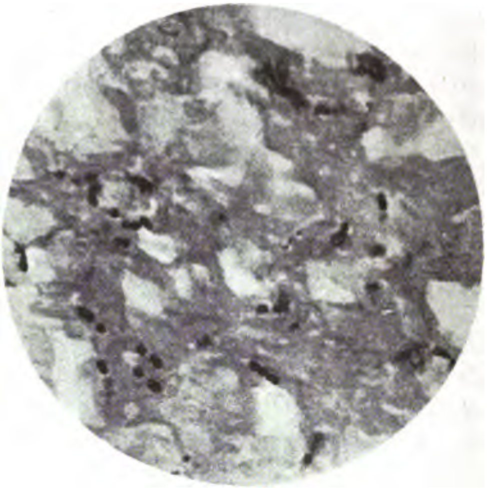

FIG. 34.—BACTERIA IN CHEESE.

A photomicrograph of curd just after curdling has taken place. Note the few lactic acid bacteria embedded in the curd.

Starters in cheese making. The starters used in cheese making are identical with those employed in butter making, and the same precautions should be observed in their propagation. It is important that the starters should not be such as to form a hard curd that cannot be mixed uniformly with the milk, since the curd particles would appear as white specks in the cheese. The starter should be added to the milk through a hair sieve, and well mixed with the milk, so as to distribute the bacteria uniformly. Amounts varying from 0.5 to 2 per cent are used. In butter making, it is essential that the bacteria of the starter be able to form not only acid, but sufficient flavor-forming substances to impart to the butter a desirable flavor. In cheese making it is not probable that this latter characteristic is of any particular importance.

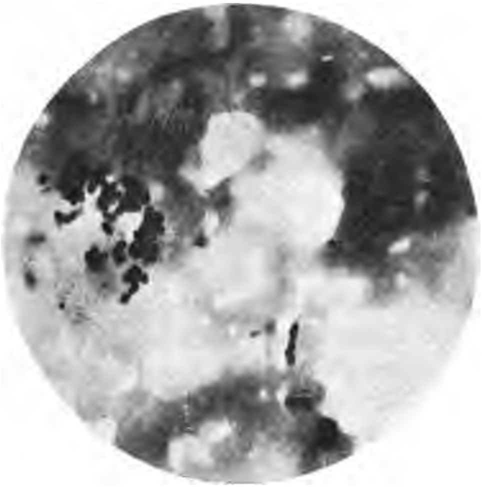

FIG. 35.—BACTERIA IN CHEESE.
A photomicrograph of curd at the time the salt is added. The lactic acid bacteria have increased materially in numbers.

Ripening of cheese. The curd at the time it is put to press is tough and rubbery, and has none of the characteristic flavor of cheddar cheese; it is also quite insoluble and indigestible. Before the cheese is fit to eat, it must pass through a complex series of changes, which are collectively known as *ripening*. In these changes there is not only a breaking down of the casein into soluble compounds, which process makes the cheese soft and plastic under pressure, but the characteristic flavor is developed in greater or less degree. A very considerable part of the cheese thus becomes soluble in water, and it is much more easily digested than in an unripened condition.

The different factors that are operative in the ripening changes are not yet fully known, but in recent years as a result of scientific study, material progress in the study of the changes has been made.

Rennet. The commercial rennet extract when in condition for use contains very few bacteria. A preservative, boric acid, is added by the manufacturer to restrain the bacteria, otherwise the extract would soon be unfit for use. The bacteria in the commercial rennet extract are too few to be of any importance whatever in the ripening process.

Rennet extract contains an enzyme, rennin, that causes the milk to curdle; also another enzyme, pepsin, that exerts a digestive action on the curdled casein. Pepsin is always found in the stomach juices of all animals, but no digestive action takes place, unless the reaction is distinctly acid, as is the case under normal conditions, since hydrochloric acid is excreted by the walls of the stomach. Outside of the stomach, the same conditions must obtain with reference to the presence of acid, if pepsin is to exert a digestive effect. In the cheese curd, the milk sugar is rapidly changed into lactic acid by the action of the bacteria. This gives the proper chemical reaction for peptic action, and the enzyme is then able to act on the paracasein, the nitrogenous part of the cheese. If milk contains no acid-forming bacteria, conditions will not permit of peptic action, and as a consequence, the ripening processes do not take place. If the sugar is fermented by some organism that does not form acid, as the lactose-fermenting yeasts, the cheese does not ripen. The lactic bacteria are therefore an essential factor in inaugurating the ripening changes in all types of rennet cheese.

Preservative action of acid. In a previous chapter it was shown that raw milk does not undergo putrefaction because of the restraining effect of the acid formed by the lactic bacteria on the putrefactive organisms. This same phenomenon is noted in cheese. Milk always contains putrefactive bacteria which pass into the cheese, but they cannot grow therein because of the high acidity. In the absence of the acid-forming organisms in the cheese, the cheese may remain tough and rubbery, on account of the lack of suitable conditions for the action of the pepsin of the rennet extract, or when the milk contains large numbers of digesting organisms, the cheese may develop a putrefactive condition, as noted by the offensive odor and soft pasty texture.

Other factors concerned in cheese ripening. There are other factors that are also concerned in the complex series of ripening changes noted in cheddar cheese. All animal fluids and tissues, if kept under perfectly sterile conditions at ordinary temperatures, will undergo a certain amount of decomposition, due apparently to their content in enzymes that have a digestive action. Meat kept in storage becomes more tender due to the softening of the connective tissue. Milk, derived as it is from actively secreting cell tissue, gives certain reactions that are common to living material. If chloroform, which restrains the action of bacteria, but does not prevent the activity of enzymes, is added to it, it will curdle in the course of a few weeks and will become partially digested. This digesting ferment found in milk is known as *galactase.* Compounds are formed in milk thus preserved that are similar to those found in a ripe cheddar cheese. Many experiments have been made with pasteurized milk, but it has not been possible to produce typical, normal cheese from thoroughly pasteurized milk. Such cheese are markedly deficient in the typical flavor of cheddar cheese. From this fact it is believed that the inherent enzymes of milk are a factor of some importance in the ripening of this type of cheese at least, if not of all types.

In the past, other factors have been thought to be of importance. Duclaux, a French bacteriologist, considered that the enzymes formed by the digesting bacteria are responsible for the ripening. It is now known that they can have but little if any part in the process, since they are not present in all cheese in sufficient numbers to have any marked effect, and since the acidity of the cheese mass will not permit of their development.

Other types of bacteria have been considered by bacteriologists to be of importance in the ripening process, but it is certain that the purely digestive change in the mass of the cheese can be accounted for through the action of the factors already noted.

Flavor production. The flavor of any type of cheese is the most important characteristic, just as it is in butter, for it is largely the flavor that determines the selling value of the product, and is the most difficult thing to control. It has been thought that the flavor-producing substances were derived from the paracasein of the curd and were produced by the factors that are concerned in the digestion of the paracasein. It has been shown that a cheese may be thoroughly ripened as far as its physical properties are concerned; that it may contain the end products of casein digestion, and yet be low in flavor. From recent researches it seems probable that the production of flavor is connected with the change that the sugar undergoes in the acid fermentation, as volatile acids, acetic, formic, etc., as well as alcohols and esters are formed in increasing amounts as the ripening progresses. These may have come from the decomposition of the milk sugar, or from a secondary change in the products of the lactic fermentation. There are organisms in both milk and cheese that do not grow on the ordinary culture media used by the bacteriologist, and it may well be that some of these are of importance in flavor production. Their destruction in pasteurization is likely to be one of the reasons for the failure of cheese made from pasteurized milk to develop typical flavor.

Effect of temperature on ripening. The temperature at which the ripening cheese are kept has been found to be of the greatest importance in determining the quality of the product. If the cheese is kept at high temperatures, the ripening proceeds rapidly; the cheese is short lived, and has a sharp, strong flavor, and generally a more or less open texture. Unless the cheese is made from the best quality of milk, it is likely to undergo undesirable fermentations when ripened at high temperatures.

Within recent years it has been found possible to ripen cheese at temperatures that were previously thought to be certain to spoil the product. Much of the cheese is now ripened at temperatures below 50° F. The ripening goes on more slowly than at higher temperatures, but the flavor of the cheese is clean and entirely devoid of the sharp undesirable tang that is so frequently noted in old cheese and the texture is solid and meaty. Ripening at low temperatures, when the milk is not of the best quality, is certain to result in a much better product than when higher temperatures are employed.

Abnormal fermentations in cheese. As has been previously shown, it is necessary to have an abundant supply of acid-forming bacteria in the milk from which cheese is to be made. If these bacteria are supplanted by other kinds, the product will be more or less abnormal, either in texture or in flavor, or possibly in both. Many of these abnormal fermentations have been studied and the organisms concerned in the changes found.

If the milk is handled carelessly, it will contain many bacteria able to form acid and gas. As noted previously, these organisms form products in milk that have an offensive odor and a disagreeable taste. In cheese the gases cause the formation of holes, more or less numerous, depending on the number of the gas-forming bacteria in the milk. Where these bacteria are abundant, gas may appear while the curd is in the vat, causing it to float in the whey, when it is known as a "floater." Again, the gas may not become evident until the cheese is in the press or on the curing shelf, when it becomes apparent by the swelling or bulging of the cheese. Such cheese is termed "huffed" or "swelled." The internal pressure may be so great as to cause the cheese to crack and to force out some of the curd. The presence of gas holes is indicative of a poor cheese, because the formation of gas is always accompanied by the presence of other undesirable compounds.

Pure culture starters are often used to overcome gassy fermentations. In cheese a certain amount of acid can be produced by the acid-forming bacteria. When the pure lactic bacteria alone are present, the cheese is very likely to be of good quality. If the sugar is fermented by gas-forming organisms, the curd will be full of holes

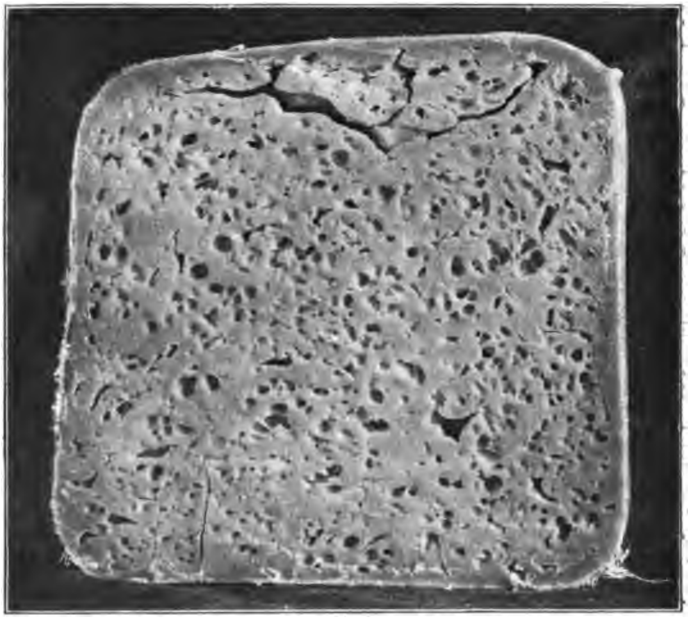

FIG. 36.—GASSY CHEESE.

Such a cheese is worthless on account of its poor flavor. The irregular holes are mechanical. The crack on the upper side is due to the pressure of the gas which has caused the cheese to bulge at this point.

and the flavor poor, while if the sugar is fermented by a mixture of the desirable and undesirable bacteria, the quality of the product will depend on the relation of the two types. If through the addition of a pure-culture starter, the proportion of desirable bacteria is increased, the gas will be lessened in amount and the cheese improved. It was formerly supposed that the lactic bacteria had an injurious effect on the gas-forming organisms. There is no good reason to believe that this is the case, but that both grow in the milk and cheese, but since only a certain amount of acid can be produced, it is important to have as much of it formed by the lactic bacteria as possible, since the amount of injurious products in the cheese will thus be limited.

The gas formed in the curd before the cheese is put to press can be gotten rid of by proper manipulation of the curd. While this treatment may improve the appearance of the cheese, it does not eliminate the substances that impart to the cheese undesirable qualities.

Gassy curds have also been treated by washing the curd with cold water. Care must be taken in applying this method for the removal of too much of the sugar and acid from the curd by the washing will permit the growth of injurious forms of bacteria. The addition of salt or of saltpeter has also been made to the milk in order to overcome gassy conditions in the milk. In the handling of gassy milk, the usual practice has been to develop a larger amount of acid before drawing the whey than in the case of good milk. This was done with the idea that acid suppressed gas formation. It has been shown previously that this is not the case. It has also been shown by Doane that the development of too much acid before drawing the whey is likely to result in undesirable flavors, producing what is known as "high-acid" or "sour" cheese.

The gas-forming bacteria grow best at high temperatures; hence, cheese kept under these conditions are more likely to be affected by this trouble than are those kept at lower temperatures.

The most successful method of preventing trouble with gassy milk in cheese making is to eliminate undesirable milk by frequent testing of the supply of the different patrons by means of the Wisconsin curd test.

Not only gas-forming bacteria may be the cause of gassy cheese but the lactose-fermenting yeasts may cause similar trouble. If these are abundant in the milk, a considerable part of the sugar may be fermented by them, in which case, carbon dioxide gas is abundantly formed. The cheese thus rendered gassy will present the same appearance to the eye as where the gas is formed by bacteria, but will have a different flavor. The odor of alcohol may be evident, and if most of the sugar has been fermented by the yeast, the acidity of the cheese may not be sufficient for the pepsin to exert its digestive action.

Milk containing many gas-forming bacteria occurs most frequently in summer. It is claimed by some that the milk of cattle pastured on low lands is more likely to contain the gas-forming organisms than that from cattle running on higher lands. If this is true, it must be due to the bacterial content of the soil; the udders of the animals become soiled as they lie on the ground, and during the milking, the dust finds its way into the pail. Many cheese makers think that the milk from an animal suffering from garget may be the cause of the huffing of cheese. This belief is undoubtedly well founded, as some of the bacteria known to be the cause of garget are gas-forming.

Bitter cheese. In a previous chapter the bitter fermentation of milk has been discussed. If milk, containing large numbers of such organisms, is made into cheese the bitterness is very likely to be noted in it. Cheese made from milk containing few or no lactic bacteria is likely to develop a bitter taste, due to the growth of the digestive bacteria that are able to grow through the lack of acid in the cheese.

If the milk contains considerable numbers of yeasts, a sweet or fruity flavor is apt to develop, due to the products of the fermentation of the sugar by the yeast. This flavor resembles that of fermented fruit, or the bouquet of certain kinds of wine.

Putrid cheese. In the absence of acid-forming bacteria, the cheese may develop a putrid or rotten odor, due to the growth of some types of putrefactive or digesting bacteria. This trouble is very infrequent in cheddar cheese, since this is made from ripened milk, but occurs more frequently in those types in which no acid is developed.

Bacteria develop in the cheese in colonies or masses, just as they do in the plate cultures of the bacteriologist, made with transparent media, such as gelatin. Cheese is opaque; therefore, the growing colonies cannot be readily discovered, but when pigment-forming bacteria grow in the cheese, their presence is likely to be noted, because of the colored spots that are formed.

Rusty spot. The ''rusty spot'' that has been encountered in New York and Canada is due to one of the colored bacteria which produces an orange or yellowish-red pigment. Various other pigment-forming organisms have been met in cheese, each producing its colored colony which differentiates itself from the mass of the cheese. If the pigment is produced in considerable quantities, and is soluble in any of the constituents of the cheese, the color will not appear in spots but will be more diffuse, or may impart a color to the entire mass.

Cases of acute poisoning arising from the ingestion of cheese are not infrequently reported; similar instances result from the use of ice cream. In both cases it is believed that poisonous products have been formed by bacteria, probably by some of the putrefactive forms.

From what has been said with reference to the abnormal fermentations of cheese, it will be seen that they are always due to the lack of acid-forming bacteria, or to their partial replacement by other types. In order to prevent such troubles, it is necessary to insure that the milk has been produced under clean conditions, from healthy cows, and has been handled in such a manner as to reach the maker in as sweet and fresh condition as possible. The maker can, by the use of proper starters, control the kinds of bacteria essential for the ripening process. A well trained maker should be able to prepare from such milk a uniform product of the highest quality. The effort of cheese makers at the present time is to handle milk of more or less objectionable quality so as to secure from it as good cheese as is possible. But cheese is so sensitive as to character of milk used that greater effort should be spent in securing an improved supply.

Moldy cheese. In the case of the cheddar cheese and other types of hard cheese, it is essential that their surfaces be kept clean, and not discolored by the growth of molds, which find favorable conditions for growth on the surface of the cheese in the moist atmosphere of the curing room. The molding of cheddar cheese can be prevented by covering the cheese with a layer of paraffin which stops the development of the mold spores, by shutting off the necessary supply of oxygen. For this purpose the cheese are dipped in melted paraffin when a few days old.

In the case of types of cheese which are salted by applying the salt to the surface, or with soft cheese which ripen from the outside, other methods of mold prevention are employed, such as rubbing and washing the cheese. The curing room itself may be freed from the mold spores by the use of such standard disinfectants as formalin or sulphur.

Swiss cheese. One of the most important kinds of hard cheese, is the Swiss or Emmenthaler, so named, from the country and valley in which the cheese was first made. In America, this type was introduced by Swiss immigrants, and is being made in constantly increasing quantities in Ohio and Wisconsin.

Swiss cheese is a hard firm type, appearing in the markets in the form of the flat circular "drum" cheese, two to three feet in diameter, and six to eight inches thick, or in the smaller "block" form. In this country the cheese is prepared twice a day, since it is necessary to work up the milk while it is perfectly sweet. Indeed, the milk is received at the factories while it is still warm, and within five or six hours after it is drawn from the cow the cheese is on the press. If the attempt is made to prepare Swiss cheese from the kind of milk that is best suited for cheddar purposes, *i. e.*, milk in which the acidity has increased to some extent, the flavor of the resulting product is likely to approximate a cheddar cheese rather than that of a Swiss.

In the salting process, the salt is not mixed with the curd before it is pressed, but is applied by immersing the cheese for a few days in a saturated brine, and then rubbing salt over the surface of the cheese. In this way the salt gradually diffuses quite uniformly through the cheese. The method of salting has apparently a marked influence on the ripening process, since if the salt is added in the same way, and in amounts used in the cheddar process, the flavor will not be that of a Swiss cheese but will resemble a cheddar.

In cheddar cheese, the whey is expelled from the curd by means of the acid which is developed in the curd, and by heating the curd to a temperature of 95° F. to 100° F. In Swiss cheese the development of acid during the making process is prevented, because of the small number of acid-forming bacteria in the milk; other factors must therefore contribute to the expulsion of the whey to secure a firm curd. This is accomplished by cutting the curd finely and by briskly stirring the same during the making, heating it during this process for a period of 20 to 30 minutes at 130° to 140° F. It might be thought that this high temperature, which is approximately that used in pasteurization would destroy the acid-forming bacteria, but these are apparently protected as they are within the curd. During the time the cheese is being pressed, the contained bacteria begin to grow and the whey coming from the cheese toward the end of the pressing shows a high acidity. If it does not show such a development of acid, the maker has reason to believe that the cheese may never ripen in a typical manner.

It has been mentioned that the milk contains but few acid-forming bacteria. The maker, however, attempts to insure the presence of a sufficient number by the use of "home-made" rennet. This is prepared by placing a piece of dried rennet, *i. e.*, the stomach of the calf, in some whey, keeping the same in a warm place for twenty-four to thirty-six hours. As the rennet contains acid-forming organisms, these grow rapidly in the warm whey, so that by adding this sour whey to the milk, the maker is not only adding rennet, that is to curdle the milk, but also a small starter of lactic bacteria. If the rennet thus prepared contain no harmful bacteria and the milk is of good quality, the cheese is likely to ripen in a normal manner. The rennet should be prepared with due regard to bacteriological principles, a condition that is rarely met in Swiss factories in this country.

Swiss cheese has two striking characteristics, the flavor and the presence of holes or "eyes." The flavor is sweetish rather than the sharp and pungent flavor of cheddar cheese. The bacteria concerned in its production are not known, but it is certain that specific organisms play some role, since if the flora of the cheese is changed by salting the curd or by the use of milk containing large numbers of lactic bacteria, the flavor will also be changed. This role of the acid-forming bacteria in Swiss is the same as in cheddar, *i. e.*, through the acid, conditions are established for peptic action, the curd being partially digested while at the same time the curd mass is protected from putrefactive processes.

In Swiss cheese during the ripening process, holes about the size of a large cherry develop which should be quite uniformly distributed throughout the cheese. The inner surface of the hole is glistening and, in a well-ripened cheese, a small quantity of clear brine, *i. e.*, "tears" may be noted. These holes or "eyes" may be called the trade mark of the Swiss cheese, since without them the product has a lessened commercial value, even if it possesses the typical flavor. The "eyes" are caused by bacteria that ferment the lactic acid produced by the lactic bacteria, forming from it propionic acid and carbon dioxid, the latter gas being the cause of the hole or "eye."

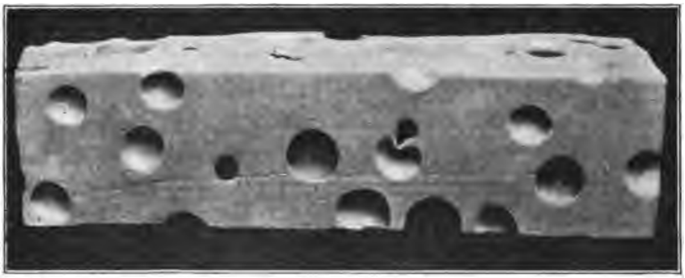

FIG. 37.—SWISS CHEESE.

Normal development of "eyes" in a Swiss cheese. The eyes are generally as large as a cherry.

The "eye"-forming organisms cannot grow in the presence of any amount of salt, hence, if salt is added directly to the curd, the cheese is likely to be "blind" or free from holes. The eyes are formed not at the time gas holes are produced in a cheddar cheese, *i. e.*, early in the ripening process, but after a lapse of three or four weeks. They are most abundant in the middle of the cheese since the manner of salting is such as to inhibit their formation near the surface. The eye-forming bacteria may have some effect on the flavor of the cheese.

The Swiss maker encounters the same troubles as does the cheddar maker. Gassy cheese is more prevalent in the Swiss than in the cheddar industry, since the maker cannot call to his aid the methods used by the cheddar maker, viz., the addition of a heavy starter, the washing of the curd, etc. It is especially important that the quality of the milk be first class in every respect, and yet customs prevail in the Swiss industry that are directly inimical to the production of good milk. The grossest carelessness prevails at the factories in the matter of handling the whey. It is often kept in individual barrels for each patron. (See Fig. 8.) These are not kept thoroughly clean and the result is that the whey taken back to the farm in the cans that are used to bring the fresh milk is often in an advanced stage of fermentation.

There are many other kinds of hard cheese; but in each, so far as is known, the role of the acid-forming bacteria is identical with that noted in cheddar and Swiss cheese, viz., in preparing conditions favorable for peptic action, and preventing the development of putrefactive bacteria present in the curd.

Roquefort cheese. Among the more important foreign types of cheese that are characterized by the development of mold is Roquefort, so named from the district in France in which it is made. This cheese is made from sheep's milk, in much the same manner as cheddar. The characteristic process in its preparation is the inoculation of the curd, at the time it is put to press, with the spores of a particular kind of mold, a type closely related to the ordinary green mold of bread and cheese. The mold for inoculation is grown on bread, the whole mass being dried so that it can be powdered; then the ground-up material is sprinkled on the curd as it is placed in the press hoops. The first stage in the ripening of Roquefort is probably identical with that of the types of hard cheeses already considered, the breaking-down of the curd being due to the pepsin of the rennet used, which action is made possible by the acid formed by the bacteria.

The second stage in ripening and one in which the characteristic flavor of the cheese is developed is due to the growth of the mold with which the cheese is seeded. Molds can grow only in the presence of air, and in order to provide this condition, the cheese are run through a machine having a series of needle-like projections which fills the cheese with fine holes. This allows the air to penetrate the cheese and the mold to grow, the fruiting of which develops the characteristic flavor. The changes produced by the mold are not well understood, but the flavor is evidently connected with its development since in the absence of mold, it does not appear. The cheese must be cured under carefully controlled conditions, as to temperature and moisture; in France these are secured by curing the cheese in limestone caves that are highly saturated with moisture. Attempts have been made to make Roquefort cheese in other parts of the world, but they have never been successful, due undoubtedly to the fact that the proper environment and conditions for the development of the various types of organisms necessary in the ripening process have not been met. This cheese is sold for 50 to 75 cents per pound in the markets of the world.

There are two other kinds of cheese that are closely related to Roquefort, as to the manner of ripening, viz., the Gorgonzola of Italy and the Stilton of England, both of which possess their characteristic flavors by reason of the development of molds. In Stilton cheese the mold is not intentionally added, the maker relying on the contamination that comes from the factory for the usual seeding. If this does not develop, it is sometimes inoculated by exchanging plugs with a well-ripened Stilton. This method is not so certain as in the inoculation of Roquefort.

Camembert cheese. A typical example of soft cheese is one of the French types, known as Camembert. This cheese is prepared from cow's milk which is curdled by rennet. The curd is not cut but is dipped into the forms, which condition, taken with the absence of pressure in forming the cheese, accounts for the large quantity of whey in it. The finished cheese are about one inch in thickness and three inches in diameter. In the ripening, the moisture and temperature of the curing room are very carefully regulated.

The first stage in the ripening is due to the rennet and the lactic bacteria. Later there appears on the surface of the moist cheese, a moldy growth. In this there are at least two kinds of molds, the ordinary mold that appears on sour milk, *Oidium lactis,* and another that is related to the bread mold but which has a white instead of a green fruiting stage. These molds are confined to the surface of the cheese but the enzymes which they produce diffuse into the substance, changing the color from a dull, opaque white to a translucent yellow. The acid that has been formed by the lactic bacteria is gradually used up by the growth of the mold, and conditions then become favorable for the growth of putrefactive bacteria which digest the curd. The cheese is ready for use when the action of the mold has penetrated to the center of the cheese, and before any pronounced putrefaction has taken place. The production of the typical flavor is dependent upon there being a definite relation between the growth of the molds and bacteria. This relation is dependent largely upon the moisture and temperature of the curing room. These cannot always be regulated with exactness; and hence, much of this type of cheese is not of first quality, and must be sold for a low price. While such fancy cheeses, as Camembert, bring fifty cents and upward per pound, and the yield from the milk is much greater than with the hard type of cheese, yet the difficulties of successful manufacture are such as to make success less easily attained than with the normal types.

There are many other kinds of soft cheese that depend for their ripening upon factors similar to those concerned in the ripening of Camembert; most of these are, however, of small importance from a commercial standpoint.

Limburger cheese. A very famous cheese is one originally made in Germany to which the name Limburger is given. It is classed as a soft cheese although it is much firmer than Camembert. This cheese is made from cow's milk and is pressed very lightly or not at all, which condition accounts for its high per cent (50 per cent) of moisture. The surface is kept moist by repeated washing of the cheese, and by keeping the air of the curing room very moist. A yellowish, slimy, bacterial layer soon develops on the surface under these conditions. The enzymes produced by this external growth gradually diffuse to the center of the cheese, when it is regarded as ripe. The odor of the matured product is somewhat putrefactive, but is not so offensive as is usually supposed.

Definite knowledge concerning the types of organisms concerned in the surface layer is very limited. It is not certain whether the same kinds of organisms must always be present. Limburger is much easier to make than Camembert, due possibly to the condition that there are not needed definite forms of life and that the balance between them is not so delicate.

A cheese known as brick is closely related to Limburger in its method of making and of ripening but is less pronounced in flavor.

In the manufacture of all of these types of cheese, troubles are likely to develop, due to an abnormal bacterial condition of the milk.

It will be seen from what has been said that the bacteria are essential factors in cheese ripening, and that the cheese industry, like the butter industry, may be called a true fermentation industry. Close co-operation must exist between the milk producer, and the maker so that the type of fermentation that goes on in the milk can be controlled. A recognition of the fundamental principles governing these fermentations, both normal as well as abnormal, is now regarded as an essential part of the training of the dairy manufacturer of today.

CHAPTER IX.

BACTERIA IN MARKET MILK.

Within the last decade attention has been especially directed toward the quality of milk that is furnished to people in cities. This has come about, in part, in connection with the demands made for better and purer food of every kind. These demands are reflected in the pure food laws enacted by the federal government, and by the various states and municipalities. Another factor that has focused attention on the milk supplies has been the recognition of its role in the production and distribution of disease, especially among children. The rapid growth of cities in all of the great countries of the world, the higher standard of living, and the greater demand for milk and other dairy products, has of necessity, widened the zone from which the milk supply of any particular city must be drawn. Milk is now an article of export and import; some of the great cities draw a portion of their supply from farms many hundred miles away. This means that a much longer time must elapse between the time of production and use. This again necessitates the exercise of greater care in production and handling, in order to preserve the milk until it reaches the consumer.

In the past, in the cities, as in the smaller towns at present, the supply was largely furnished by the producer directly to the consumer. This direct contact afforded the consumer the opportunity, if he desired.

of informing himself of the conditions under which his milk supply was produced. The advent of the middle man in the business, and the gathering of the milk from many hundreds of farms, and its redistribution to thousands of consumers has made it impossible for the individual consumer to learn anything of the conditions surrounding production. When the individual cannot protect himself against fraud and unhealthful conditions, it is the business of the government to protect him. This is the theory for the modern control of food supplies, water supplies, and of living conditions in general. Acting on this basis the cities are seeking to control to an increasing degree, the healthfulness and cleanliness of the milk supply.

Formerly the control was largely with reference to the composition of the milk, the regulations providing that it should contain not less than a minimum amount of fat and other solids, and be free from preservatives. The more modern regulations are much more complex and touch every phase of production and handling that can, in any way, affect the value of the milk as human food.

Municipal regulations. The various cities vary widely in the regulations which are imposed upon the farmer and upon the milk dealer, and in their methods of enforcement. In an appendix to this chapter are given the rules that a modern milk company is willing to impose upon itself. Copenhagen has long been recognized as the most progressive city of the world, as far as its milk supply is concerned. There is probably no other large city where the same grade of milk can be obtained at the same price, as in the Danish capital. The conditions given in these rules cover practically all points that are necessary to consider in formulating regulations for this purpose.

Milk is subject to contamination during all stages of its handling, not only with the putrefactive bacteria but with disease-producing organisms as well. It is best adapted for human food in the condition in which it is drawn from the udder of the healthy cow. The effort should be to deliver it unimpaired to the consumer.

Number of bacteria in milk. When the milk is drawn from the udder of a healthy cow, it will contain a few hundred bacteria per cubic centimeter. The immense numbers that are found in market milks emphasizes the contamination from other sources, that have been previously detailed, and the growth that occurs. The average bacterial content of the milk supply of Washington, D. C., for 1906 was 22,134,000 per cubic centimeter; for 1907, 11,270,000 per cubic centimeter. About 90 per cent of the samples of the Boston supply examined in 1906 contained less than 500,000 bacteria per cubic centimeter. The number of bacteria in any sample of milk is dependent upon (1) the original amount of contamination, (2) the age of the milk, and (3) the temperature at which it has been held. A high bacterial content is indicative of poor milk, while a low bacterial content can only be obtained, in the case of raw milk, where due attention is paid to cleanliness and cooling. This relation between the quality of milk and its bacterial content has led many cities to establish numerical bacterial standards. Boston requires that the milk shall not contain more than 500,000 bacteria per cubic centimeter. Rochester, N. Y., has a standard of 100,000 per cubic centimeter, while Chicago requires that the milk on arrival in the city shall not contain more than 1,000,000 per cubic centimeter from May first to September thirtieth, and not over 500,000 between October first and April thirtieth. The sale of milk containing more than 3,000,000 bacteria per cubic centimeter is prohibited.

It has been urged that bacterial standards are not of value since the healthfulness of milk depends on the kind of bacteria present rather than on the number. It is well recognized that milk containing millions of acid-forming organisms is a healthful food, as in butter milk, while milk containing many less bacteria may also contain some pathogenic organisms. It has been urged that a qualitative standard should supplant the quantitative. The consumer desires milk that has been produced under clean conditions, and which has good keeping qualities; but the harmless forms of bacteria exert the greatest influence on the keeping quality. Experience has shown that the quantitative examination of the milk supply as it comes from the farm is the most feasible method of determining, in the laboratory, whether the farmer has obeyed the rules of the city with reference to cleanliness and cooling of the milk. The bacteriological examination also gives an indication as to whether the large number of bacteria are due to gross contamination of the milk with mud and manure, or actual growth of bacteria as in old milk. In the latter case the ordinary acid-forming bacteria will usually predominate in the milk, while in the former, the number of kinds of bacteria and the proportion between the kinds will be changed. It is of course evident that the quantitative standards should be applied with judgment.

It is also claimed that the delay in securing the results in the quantitative examination of milk is an objection to the bacterial standard, since the milk is consumed before results can be obtained. It is true that it does not protect the community as far as the particular sample is concerned, but it is also true that the examination is not made for the purpose of determining the condition of the particular sample, so much as it is to determine the methods that are employed on any particular farm, and these do not vary widely from day to day. Thus, if a number of samples give high results, it is evident that conditions surrounding production need investigation.

If the milk is well cooled on the farm, and kept cold while being shipped, the growth of bacteria will be slow, and the condition of the milk as far as keeping quality is concerned, much better than if less care is used. Some cities have temperature standards; New York requires that the milk shall be cooled to 50° F. on the farm, and shall not be above 50° F. on arrival in the city. Others require that it shall not be above 50° F. on delivery to the consumer.

Tests for the quality of milk. At the milk depot and elsewhere, it is frequently desired to determine the bacterial condition of the milk in a less refined manner than by the plate cultures of the bacteriologist, which require a large amount of time for their preparation and do not yield any positive information for at least twenty-four hours. There are a number of such tests that may be applied.

1. *Dirt test.* The dirt test is used in European dairies. It is carried out most frequently by filtering a quart of the mixed milk through a small disc of absorbent cotton. The insoluble dirt is retained and imparts a color to the cotton, the shade of which is dependent on the amount of dirt. Since it is impossible to have dirt without bacteria, it is evident that milks containing a

large amount of dirt will be high in bacteria. The reverse, however, is not necessarily true.

2. *Acidity test.* The acidity of the milk is also an indication of its bacterial content. If the acidity has increased, above the normal for fresh milk, the bacterial content is certain to be high, and the keeping quality poor. An acidity above 0.2 per cent in market milk is to be avoided, as an increase in acidity is always preceded by a rapid growth of bacteria.

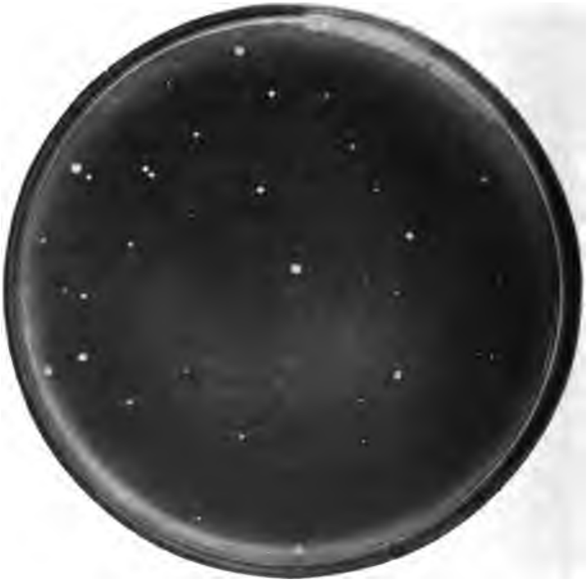

FIG. 38.—GOOD MILK.

A plate culture inoculated with 1/100 of a cubic centimeter of milk containing 67 colonies, which equals 6,700 bacteria per cubic centimeter of milk. Such milk will keep well.

The acidity can be rapidly and easily determined at the receiving station by a modification of the Farrington acid test. Dissolve one alkaline tablet to the ounce in water. A unit volume of this solution added to a unit volume of milk is equal to 0.1 per cent of acidity. If two measures are provided,—one for the alkaline solution holding just twice as much as that used for the milk, the approximate acidity can be quickly determined by mixing a measure of each in a common white cup. If the acidity is above 0.2 per cent the color will remain white; if a pink

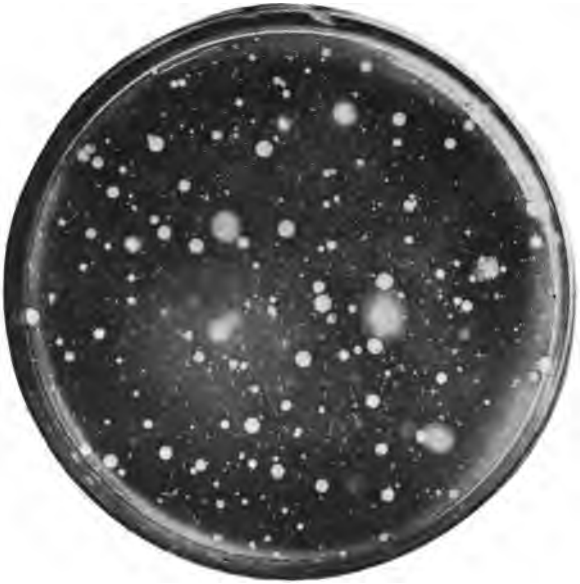

FIG. 39.—POOR MILK.

A plate culture inoculated with 1/1000 of a cubic centimeter of market milk containing 1,680 colonies, which equals 1,680,000 bacteria per cubic centimeter. Such milk has poor keeping qualities.

color develops, it indicates an acidity less than this amount. This test is also useful in the selection of milk or cream that is to be used for especial purposes, as in pasteurization.

3. *Alcohol test.* A test giving similar information is made by adding two parts of 70 per cent alcohol to one part of milk, and noting whether curdling occurs.

The curd test described on p. 100 gives no indication of the number of bacteria present, only concerning the types present. It has been proposed to combine the fermentation test with the reduction test referred to below and thus gain some idea of, not only the number, but the kinds of bacteria present.

4. *Reduction test.* The reduction test is made by adding to twenty cubic centimeters of milk, one-half cubic centimeter of a solution of methylene blue, a coal tar dye. A saturated solution of the dye is made in alcohol, and 2.5 per cent of this solution added to water. The time required for the reduction of the dye or the change of the color from blue to white when the samples are placed in tubes and kept at 98 to 100° F., is dependent upon the number of bacteria present. By allowing the tubes to stand until curdling occurs, and noting the nature of the curd, whether the solid curd of the desirable acid-forming bacteria or the gassy curd of the harmful types is produced, knowledge is gained of the kinds of bacteria present.

According to Barthel milks that reduce the methylene blue within fifteen minutes contain hundreds of thousands of bacteria per cubic centimeter. Those that require from fifteen minutes to one hour for the disappearance of the color are also high in bacteria, and are to be classed as a poor grade of market milk. If one to three hours is required, the milk is comparatively low in bacteria, and is to be classed as a good grade of market milk. When more than three hours elapses before the disappearance of the blue color, the bacterial content is low and the milk is to be placed in the highest grade.

The time of reduction is only a rough index of the number of bacteria present, but it gives a good idea of the keeping quality of the milk, and of the conditions of production and handling. In connection with the fermentation test that can be carried out with no additional trouble, this test should be of value to the dairy manufacturer.

Examination of milk sediments. In the modern municipal laboratory, efforts are made to determine, as far as possible, the conditions of production on the farms, by an examination of the milk in the laboratory. The samples of milk are sedimented in a small centrifuge, and an examination of the sediment made with the microscope. The types of bacteria and the number of white blood corpuscles found, is an indication as to whether any of the animals of the herd are suffering from inflammation of the udder. The test also gives information similar to the dirt test since the insoluble dirt will be thrown down and will impart a color to the sediment.

Grades of milk. Many of the American cities have provided for the sale of different grades of milk, the basis for such classification being the care used in its production and handling. The following grades are legal in the city of New York, which, on account of the activity of its Department of Health, is supposed to have the best milk supply of any large city in this country.

Market milk. This term is applied to milk which conforms to the following regulations and which does not meet the requirements of milk sold under other grades. Milk is classed as adulterated (1) when it contains more than eighty-eight and one half per cent of water or fluids; (2) when it contains less than eleven and one half per cent of solids; (3) when it has less than three per cent of fats; (4) when drawn from animals within fifteen days before or five days after parturition; (5) when cows are fed on distillery wastes or on any substance in a state of fermentation, or putrefaction, or on any unwholesome food; (6) when drawn from cows kept in a crowded or unhealthful condition; (7) when any part of the cream has been removed; (8) when the milk has been diluted with water or with any other fluid, or when any foreign substance has been added thereto; (9) or when the temperature is higher than 50° F. or when it contains an excessive number of bacteria.

Selected milk. The minimum requirements for this grade are that only such cows shall be admitted to the herd as are free from all diseases of the udder, and from clinically manifest tuberculosis; that all cows shall be examined clinically each year by a veterinarian of the department of health; that all cows with any disease of the udder, or with clinically manifest tuberculosis, to be excluded from the herd and farm. It is declared unlawful to use the milk of any such cows for food purposes. Moreover, the milk shall never contain per cubic centimeter more than 60,000 bacteria in winter, nor more than 100,000 in summer; that such milk shall be delivered to the consumer only in sealed bottles, which have been filled at the dairy or creamery, and which shall be labeled with the date of the earliest milking whose milk forms a part of the contents of the bottle; that such milk shall be delivered to the consumer within thirty-six hours after milking.

Guaranteed milk. The minimum requirements for this milk are that only such cows be admitted to the herd as have not reacted to a diagnostic injection of tuberculin; that all cows be tested annually with tuberculin, and all reacting animals be excluded from the herd; that the milk shall not contain more than 30,000 bacteria when delivered to the consumer. The requirements as to dating and time of delivery are the same as for selected milk.

Pasteurized milk. The city also provides for the sale of pasteurized milk which must be delivered to the consumer in sealed containers that are labeled "pasteurized" and with the date and hour when pasteurized, the degree of heat employed, the length of time exposed to the heat, and the number of the pasteurization permit issued by the department of health. The pasteurized milk must be delivered to the consumer within twenty-four hours of pasteurization, and no milk may be pasteurized a second time.

Milk or cream that has been heated can not be sold unless the heating conforms to the following:

158° F. for........	3 minutes	148° F. for........	15 minute
155° F. "........	5 "	145° F. "........	18 "
152° F. "........	10 "	140° F. "........	20 "

The pasteurization shall be done in apparatus that is equipped with automatic temperature and time regulating and recording devices.

It is deemed essential that all pasteurized milk be sold as such, since the consumer is accustomed to look upon the souring of the milk as an indication of its unfitness for use. The pasteurization, if effectually done, destroys the acid-forming bacteria, and the milk is then exposed to the attacks of the spores of the putrefactive bacteria, whose action on the milk may be less evident, and far more harmful than that of the acid-forming organisms. It is also very important that the pasteurized milk be used as soon as possible after pasteurization, as the putrefactive bacteria, free from the injurious influence of the acid, grow with great rapidity if the milk is not well refrigerated.

Certified milk. In many cities the Medical Societies have appointed Milk Commissions, that adopt rules and regulations, concerning the production of milk that shall receive the certificate of the commission. Producers, who desire to have their milk thus certified, must satisfy the commission that they are able to conform to the rules. The commission appoints a physician to examine the personnel of the farm, a veterinarian to make frequent examination of the herd, a chemist to examine the milk as to its contents in fat and solids, and a bacteriologist to determine the bacterial content of the milk. The rules are very stringent and cover every point that may influence, in any way, the value of the milk as human food. In order to conform to these requirements, a heavy expenditure must be incurred, the business must pay for such expert service; hence, certified milk must be sold at high prices, twelve to twenty-five cents per quart. This price makes it a special product and its use is confined mainly to infant feeding.

The bacterial standard for certified milk is usually 10,000 bacteria per cubic centimeter. It is only by the exercise of the greatest care at every point that the bacterial content can be kept below this maximum.

The term "certified milk" has been registered by Mr. Francisco of New Jersey, who was the first to engage in the production of such milk under the direction of the Medical Milk Commission of Essex County, New Jersey. The use of the term is allowed when the milk is produced under the regulation of any Medical Milk Commission.

Most certified milk is now produced on fancy dairy farms conducted by wealthy men. The barns and other equipment are the best that can be obtained, and the methods employed, as far as cleanliness is concerned, are extreme. In some of the dairies the bacterial content is reduced to a few hundred per cubic centimeter, or to that which is derived from the interior of the udder. Such milk will, when well refrigerated, keep for long periods of time. It is a not uncommon experience with such milk, for it to keep perfectly sweet for ten to fifteen days.

Farm inspection. Cities seek to determine whether the producers are conforming to the regulations of health departments by an examination of milk samples that are collected in the city. If the milk is collected at a central place in the country and that of many farms mixed, such an examination gives no indication of the conditions obtaining on any particular farm. Cities are, therefore, sending inspectors to the country to inspect the equipment and methods used on the farms, and in order to make such an inspection as effective as possible, and to remove the personal element, are making use of the score card system that has been found so effective in other lines. There is here reproduced the card used by the city of New York.

DEPARTMENT OF HEALTH

The City of New York

Division of General
Sanitary Inspection

Dairy Report

Inspection No........Time........A. P. M. Date................191..
1 **Dairyman**........................ **Owner**..........................
2 **P. O. Address**.................. **P. O. Address**........State.......
3 **County**...........State.......... **Party Interviewed**.............
4 Milk delivered to Creamery at.................Formerly at................
5 Operated by.........................Address..............................
6 Distance of farm from Creamery..............Occupied farm since.........
7 No. Cows...............No. Milking............No. Qts. Produced..........
8 All persons in the households of those engaged in producing or handling milk are..........free from all infectious disease. Weekly reports are ....being filed ....
9 Date and nature of last case on farm..
10 **WATER SUPPLY** for utensils is from a............located............ feet deep and apparently is........pure and wholesome.................. State any possible contamination located within 200 feet of source of water supply or if water supply is not protected against surface drainage ....
....
11 Water supply on this farm analyzed.............191.. Result.............
12 Style of Cow Barn....Length....ft. Width....ft. Height of ceiling....ft.
13 **Dairy Rules** of the Department of Health are......posted................
14 **Dairy Herd** examined by...........on...........191.. Report..........

	PERFECT	ALLOW
EQUIPMENT		
15 **COW STABLE** is....located on elevated ground with no stagnant water, hog-pen, privy, uncovered cesspool or manure pit within 100 feet........................	1	....
16 **FLOORS,** other than cow beds. are........of concrete or some non-absorbant material......................	2	....
17 Floors are......properly graded and water-tight.........	2	....
18 **Cow beds are**..of concrete or planks laid on concrete..	2	....
19 **DROPS** are....constructed of concrete, stone or some non absorbant material..................................	2	....
20 Drops are........water-tight and space beneath is clean and dry..	2	....
21 **CEILING** is constructed of.......and is......tight and dust proof..	2	....
22 **WINDOWS** No........total square feet........there is ....2 square feet of window light for each 600 cu. ft. air space (1 sq. ft. per each 600 cu. ft.—1)	2	....
23 **VENTILATION** consists of....sq. ft. muslin covered openings or....sq. ft. open chutes in ceiling or......... ....which is sufficient 3, fair 2, poor 1, insufficient 0	3	....
24 **AIR SPACE** is......cu. ft. per cow (600 and over—3) (500 to 600—2) (400 to 500—1) (under 400—0)...........	3	....
25 **LIVE STOCK,** other than cows, are....excluded from rooms in which milch cows are kept..................	2	....
26 There is..........direct opening from stable into silo or grain pit...	1	....
27 Separate quarters are...........provided for cows when calving or sick.....	1	....
28 **COW YARD** is....properly graded and drained.......	2	....
29 **WATER SUPPLY** for cows is........unpolluted and plentiful..	1	....
30 **MILK HOUSE** has...........direct opening into cow barn or other building..................................	1	....

		PERFECT	ALLOW
31	**Milk house has**......sufficient light and ventilation.......	1	....
32	**Floor is**........properly graded and water-tight..........	1	....
33	**Milk house is**....properly screened to exclude flies.......	1	....
34	**Milk pails are**...........of smoothly tinned metal in good repair..	1	....
35	**MILK PAILS have**......all seams soldered flush......	2	....
36	**Milk pails are**............of the small mouthed design, top opening not exceeding 8 inches in diameter, Diameter	2	....
37	**Racks are**........provided to hold milk pails and cans when not in use..	2	....
38	**Special milking suits are**..........provided..........	1	....
		40	

METHODS

		PERFECT	ALLOW
39	**STABLE INTERIOR** painted or whitewashed on.... ....which is satisfactory 3, fair 2, unsatisfactory 1, never 0..	3	....
40	**FEEDING TROUGHS,** platforms or cribs are...... ....well lighted and clean..........................	1	....
41	**Ceiling is**..............free from hanging straw, dirt or cobwebs	3	....
42	**Window panes are**......washed and kept clean......	1	....
43	**WALLS AND LEDGES** are........free from dirt, dust, manure or cobwebs..........................	2	....
44	**FLOORS AND PREMISES** are........free from dirt, rubbish or decayed animal or vegetable matter....	2	....
45	**COW BEDS** are.......clean, dry and no horse manure used thereon..	2	....
46	**Manure is**........removed to field daily 4, to at least 100 feet from barn 2, stored less than 100 feet or where cows can get at it 0..................................	4	....
47	**Liquid Matter is**........allowed to saturate ground under or around cow barn..........................	2	....
48	**Milking stools are**...........clean....................	1	....
49	**Cow Yard is**........clean and free from manure........	2	....
50	**COWS have**........been tuberculin tested and all tuberculous cows removed..................................	7	....
51	Cows are........all in good flesh and condition at time of inspection..	2	....
52	Cows are..........all free from clinging manure and dirt. (No. dirty...........)...........................	4	....
53	**LONG HAIRS** are........kept short on belly, flanks, udder and tail..	1	....
54	**UDDER AND TEATS** of cows are........thoroughly brushed and wiped with a clean damp cloth before milking	3	
55	**ALL FEED** is........of good quality and distillery waste or any substance in a state of putrefaction is.... ....fed	2	
56	**MILKING** is........done with dry hands.............	2	....
57	**FORE MILK** or first few streams from each teat is.... ....discarded	2	....
58	**Clothing** of milkers is........clean.....................	1	....
59	**Facilities** for washing hands of milkers are ....provided in cow barn or milk house.......................	2	....
60	**Milk** is strained at..........and ....in clean atmosphere	1	....
61	Milk is........cooled within two hours after milking to 50 degrees F. 3, to 55 degrees F. 2 to 60 degrees F. 1....	3	....
62	Ice is........used for cooling milk......................	1	....

	PERFECT	ALLOW
63 **MILK HOUSE is**........free from dirt, rubbish and all material not used in the handling and storage of milk..	1	
64 **Milk utensils are**........rinsed with cold water immediately after using and washed clean with hot water and washing solution..................................	2	
65 Utensils are........sterilized by steam or boiling water after each using......................................	2	
66 **Privy** is........in sanitary condition, with vault and seats........covered and protected......................	1	
	60	

Remarks ....

Equipment 40 per cent. Score............per cent
Methods 60 per cent. Score................per cent
Perfect Dairy 100 per cent. Score........per cent

Considerable variation is to be noted in the type of score cards used by different cities. This method of standardizing is also used for the inspection of creameries and milk stores in the cities. The essential point to which attention is paid is the prevention of the contamination of the milk, especially with disease-producing bacteria. A common requirement is that milk shall not be shipped from any farm on which there is a case of any transmissible disease, as typhoid fever, diphtheria, or scarlet fever. The only way in which such a rule can be made effective is to provide that the milk shall be kept on the farm, but that the farmer shall receive pay for it from the milk company. There is then no incentive for the farmer to conceal cases of disease. Such a procedure will increase the cost of the milk to a slight extent, but the consumers should be willing to pay it as an insurance against disease.

Milk distribution. Until within recent years in the cities and at present in smaller towns, milk is largely retailed from cans which are carried on the wagons or are kept in stores. This exposes the milk to contamination from street dust and from the container furnished by the consumer. It is well recognized that every utensil with which milk is brought in contact adds more or less bacteria to it, and the less milk is handled, the better will be its condition when it reaches the consumer. Milk is now largely retailed in glass bottles which are closed with pulp caps. In some cities the bottling is mainly done in the country at the bottling station to which the milk is brought by the farmers; or it may be shipped by the producer to a distributing company, and all subsequent treatment, as pasteurization and bottling done in the city.

Milk plants are now generally equipped for the rapid and economical handling of large quantities of milk in a most sanitary manner. The bottles as they are returned from the consumer are washed in a continuously-acting automatic washer which washes, rinses and sterilizes the bottles without their being removed from the cases in which they are carried on the wagons. These machines are effective, if not run at too rapid a rate, so that the bottles are not exposed for a sufficiently long period of time to sterilize them. The bottles are then filled and the paper caps inserted by machinery. The caps can now be obtained from the manufacturers in sealed tubes in which they have been sterilized so that the contamination from this source is avoided. The shipping cans are washed and sterilized with live steam, and in many plants are thoroughly dried, by passing hot air into them. Under these conditions they then reach the farmer with none of the musty and disagreeable odor that frequently is present when the can contains a small quantity of water, condensed from steam.

The top of the milk bottle over which the milk is poured is exposed to contamination from the hands of the deliveryman. Trouble from this source can be avoided if the consumer cleans the lip of the bottle before removing the cap. The better grades of milk are dispensed in bottles, the top of which is protected by an additional cover of paper or tin foil which reaches to the neck of the bottle and is held in place by a crimped metal band.

It may be said that the milk now furnished by the large milk companies of the cities is of higher grade than ever before; while that retailed from the stores and by the small dealer in the city and in the small town is still much in need of improvement.

The duty of the consumer. The educational campaign that has been carried on by the health departments with reference to farm conditions and methods of handling has been most effective in improving the milk supply. Many cities are now extending this to the consumer, recognizing that as much harm may be done in the home as on the farm. The importance of keeping the milk cold, of not allowing it to stand exposed in open vessels, of thoroughly cleaning the vessel in which it is kept, or the milk bottle before returning it to the milkman are especially emphasized.

Moreover, it must be impressed upon the consumer that all of these improvements, not only on the farm where the milk is produced, but in the hands of the distributing companies in the cities, involve much expense, and cannot be carried out, unless the consumer is willing to pay their cost. More objection seems to be raised over an increase in the price of milk than any other food stuff. The consumer therefore needs education along the line of higher prices for milk. Dairy products of all types have increased much in value in recent years, so that at present prices milk, sold directly as milk, is relatively cheaper than in any form, when prevailing prices are compared with those that obtained a decade ago.

APPENDIX.

The rules which a Danish milk company is willing to impose upon itself are illustrated in those of the Trifolium Milk Supply Company of Copenhagen. The work of the company is under the supervision of a committee of control consisting of a physician and a veterinarian. The obligations of the company to the committee of control are as follows:

Milk may be taken only from herds that have been approved by the committee, and that furnish milk containing at least 3 per cent fat. Nursery (children's) milk shall come only from herds that are proven to be entirely free from tuberculosis by the use of the tuberculin test, and these herds shall be retested at least once a year. Milk may be received from a tuberculosis-free part of a herd only after the committee has investigated the conditions, and has given its approval. In this case, the healthy part of the herd is to be kept entirely apart from the reacting section, it is to be retested at least once a year, and the reacting animals are gradually to be disposed of. If a calf plague (calf cholera, contagious pneumonia, pyaemia, etc.) occurs in the herd the committee may require shipments of milk to be discontinued until further notice.

The company pays one or more veterinarians, who are appointed by and are responsible to the committee of control.

Farms that supply the regular whole milk, skimmed milk and cream are to be inspected by the veterinarian twice a month, unless in summer the cows are kept stabled, in which case four visits per month are to be made. Herds that supply nursery milk are to be inspected the year through four times a month. Traveling expenses are paid by the company.

Nursery milk is to be shipped only in containers that are easily distinguished by their shape and color from the containers used for the regular milk.

The company shall not employ any weakly persons, nor any that are afflicted with an infectious disease or with any repulsive skin disease, as tuberculosis or syphilis. Any employee so affected is to be dismissed. If any one of the employees shall contract typhoid fever, gastric fever, diphtheria, scarlet fever, erysipelas or any other virulent infectious disease, the affected person shall not come upon the premises of the company or resume his work until he shall present a certificate from a physician to the effect that he is no longer capable of conveying infection. The same applies to employees in whose dwelling any of the above named diseases may occur.

If any one of the employees shall be afflicted with discharging or suppurating wounds on the face, hands or arms or with any transmissible or repulsive disease or with severe diarrhoea, the affected person shall not be employed, during the continuance of the condition, in any work in which he would come into direct or indirect contact with milk, nor shall he be permitted to wash bottles.

Every employee who may not work on account of illness, or on account of disease in his family, *is to receive his full pay as though working.* A physician is appointed with whom the employees and the members of their families may consult and who shall make frequent visits to the dairy premises and keep an oversight of the employees as to their health. The company shall keep a special record showing the employees that are ill, when they are laid off, and the nature of the illness.

The milk shall be cooled to 41° F. as it is received from the producers and shall be kept at this or a lower temperature.

All containers are to be thoroughly cleaned by a method approved by the committee. The bottles for nursery milk are to be cleaned and heated in accordance with the instructions of the committee.

The herds and all of the premises connected with the business are to be open to the members of the committee at all times. All necessary traveling expenses are to be paid.

All announcements and communications regarding the business, so far as these relate to the technical matters under the supervision of the committee, are to be approved by the committee before they are published.

A member of the committee of control shall be privileged to resign (a) at any time when in his opinion the hygienic regulations relating to the conduct of the business are not properly observed, and similarly, if later regulations made by order of the committee are not complied with, or (b) (under other circumstances) he may resign after three months' notice.

The health of the herds. The producer must agree to permit the veterinarian of the company to examine his herd as often as may be considered by the company to be necessary and he must give the veterinarian such information as he may desire in regard to the herd, the feeding and the milk. The producer must agree to observe the instructions of the veterinarian.

The cattle that are designated by the veterinarian as tuberculous are to be removed from the herd at once, and, as soon as possible, they are to be sold or killed. Cattle that are for any other reason picked out by the veterinarians are, as he directs, to be removed from the stable or placed apart at one end; the milk may not be used and the cows may not be restored to their places with the herd until permission is given. In case disease occurs between the visits of the veterinarian, and especially any of the following,—tuberculosis, inflammation of the udder, inflammation of the uterus, severe diarrhoea,—the affected animal or animals are to be isolated and their milk must not be used. The company will continue to pay for this milk until the veterinarian makes an inspection. If a number of cows become diseased in such a way as to suggest the outbreak of an epizootic or poisoning, the veterinarian and the business manager are to be notified at once by telegraph or telephone. The milk of newly purchased cows may not be used until these cows have been examined by the veterinarian and approved.

The producers of nursery milk are obligated to add no cows to their herds until they have been tested with tuberculin and are declared by the veterinarian for the company to be healthy. All the cows of the herd are to be tagged by the veterinarian. The producer of nursery milk is required to have his herd tested with tuberculin at least once a year. The records of test are to be submitted by the veterinarian of the company to the committee. If there is maintained on a farm a herd of reacting cows, the producer is required to dispose of these gradually, and to take care that there is no contact between the healthy and the reacting cattle.

The health of the personnel. The producer is required to observe the following rules in relation to the health of the persons who work in the stable or with the milk.

No one may be employed who is affected with tuberculosis or syphilis. Persons who have discharging or suppurating sores or wounds on the face, hands or arms, or a disease of the skin in these regions, or that have a severe diarrhoea are not under any circumstances to be permitted to come in contact with the milk. Persons who live in a house where there is typhoïd fever, gastric fever, diphtheria, scarlet fever or any other virulent infectious disease are, likewise, positively prohibited from coming in contact with the milk, until the local physician certifies that they are no longer infectious. If, nevertheless, such persons should by accident come in contact with the milk, it is to be held back (not shipped) *and the company will pay the usual price for it,* unless the contamination was the result of connivance on the part of the producers. The producer is required to use all possible care in keeping informed as to the condition of health of his employees so that every case of infectious disease may be discovered and isolated as soon as possible.

Once a year a statement is to be submitted from the local physician to show the state of health of persons on the farm and all cases of infectious diseases that he treated on the farm during the preceding half year.

If a case of typhoid fever, gastric fever, diphtheria, scarlet fever or any other virulent infectious disease occurs among the people living at the farmstead or among the people employed on the farm, the producer is obligated to notify immediately the manager of the company by telegraph or telephone. The milk shall be held back and shipments may not be resumed until the committee of control has given permission. For all milk that is held back under these circumstances *the company will pay full price.*

Feeding and care of the cows. All food must be quite fresh (not deteriorated). Moldy or otherwise damaged food must not be in the stable or in the immediate vicinity. The veterinarian of the company has the right to inspect the food.

In summer, so far as is possible, the cows are to be fed in the pasture. If it is necessary to feed them in the stable, the company is to be notified and then the producer is required to use care that the stable and the cows are kept as clean as possible. The company reserves the right to forbid, if it is considered necessary, the stable feeding of cows that produce nursery milk.

The veterinarian shall be advised as to the composition of the feed. The following rules shall apply:

No roots may be fed to cows producing nursery milk except carrots and sugar beets, and of these not more than forty pounds per day. Cows producing regular milk may receive as much as sixty pounds per day, providing this amount does not cause diarrhoea. Beet tops, beet trimmings, cabbage, distillery slops, malt, etc., may not be fed. For cows producing nursery milk, the following foods are prohibited: molasses, cotton seed meal, green or dry buckwheat and mustard. These feeds may be given to other cows but only in small quantities. Molasses must not be used if it produces any undesirable effect. If rape seed is used, it must not contain any considerable amount of oil of mustard, and before it is used it must be shown to the official veterinarian. The producer is required, so far as possible, to forbid frequent and sudden changes of feed.

Before the cows are stabled in the fall, the hair is to be clipped from the udder, tail and thighs.

The use of the milk is forbidden until ten days after calving. The milk shall not be used from cows that give daily less than three quarts.

The care of the milk. Milking must be conducted with the highest degree of cleanliness and care. The following specific rules shall apply: Each milker must always wear a milking suit and must be supplied with a towel. Clean water must be supplied in ample amount, so that the hands may be washed as often as necessary. The stable must be so well lighted, and especially behind the cows, that those who do the work can see clearly enough to perform their work in an orderly and clean manner. Immediately after milking, the milk is to be passed through a fine metal strainer, which must be cleaned frequently. The milk is to be cooled before it is shipped, at all seasons, and just after milking, by the use of a cooler, to at least 46.4° F.

Cleaning the stable shall not take place until after the morning milking, and in the afternoon it must be completed at least one hour before milking. Fresh cows, cows that give less than three quarts a day, and cows that have been separated from the herd by the veterinarian shall have places at the end of the stable, so that it will not be possible for the milkers to mix their milk with that of the cows producing milk for the use of the company.

A sufficient supply of ice shall be available. For cooling, an apparatus is to be used that is set up in a light clean room that is used for no other purpose, and each time, before used, it is to be rinsed off with clean water. The producer agrees to follow the instructions regarding cleanliness in the stable and the care of the milk that may be given him by the company or by their veterinarian.

Delivery. In the summer the transport wagons must be supplied with a cover to protect the milk cans from the sun. Feed, fertilizer, etc., must not be carried on the same wagon with milk or with the cleaned milk containers.

The company furnishes the cans used for the transportation of the milk. Those used for nursery milk must not be used for other milk. Under no circumstances shall the cans be used for any purpose other than to send milk to the milk station. The cans are cleaned by the company before they are returned. The producers are to rinse the cans in clean cold water, and, if soiled during transportation, they are to be cleaned. The producer is required to furnish a supply of good water for the cows and for cleaning the vessels and utensils that come in contact with the milk. Any suspected defect of the water supply is to be reported at once to the committee on control.

Other provisions. The producer agrees to answer truthfully and honestly all questions from the company in regard to the milk supply. It is agreed that the herds and premises where the milk is handled and cared for shall be open at all times to the members of the committee on control.

Instructions to the veterinarians. The veterinarians are appointed and can only be dismissed by the committee on control and all instructions come from the committee. A report is to be rendered to the committee on every visit to a herd, and this shall contain information in regard to: the total number of cows, the cows in milk, all cases of disease, whether cows have been sold or killed that were isolated as suspicious or diseased, the condition of the whole establishment in regard to cleanliness, the method of feeding and remarks on any pertinent subject.

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